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CHARLOTTENLUND SLOT – DANEMARK

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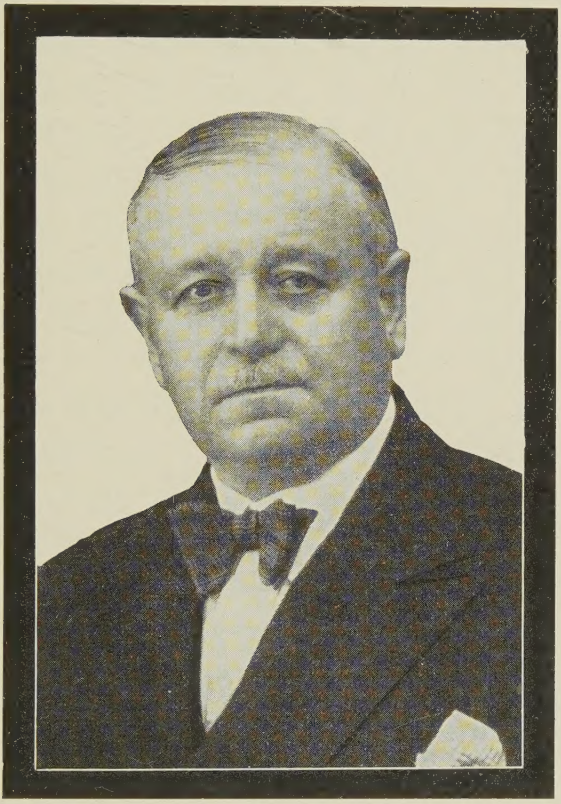
Erratum.

Vol. XII, No. 1., p. 19, line 7

"Where as elsewhere we only" — should read: "where as elsewhere on spawning grounds we only".

A/S L. IHRICH - COPENHAGEN



S. K. Asserson.
(1882—1937).

THE sudden death of S. K. ASSERSON, the Norwegian Fisheries Director, at Oslo on the 19th July was very sad news to the many in Norway and elsewhere who had had the good fortune to become acquainted with his very likeable personality;

it was a severe loss to his country, especially to the fisher-folk and all those connected with the fisheries. He took up his position when the fisheries were in a very difficult situation, and all his powers and capacities were immediately absorbed in the great task of safeguarding the interests of the fisheries and the population dependent upon them during the great economic and social changes which have occurred in quick succession ever since the war started.

Asserson was born at Sandnes, near Stavanger, in 1882; the son of a seafaring man, his interest in everything connected with the sea was inborn and genuine. Although his professional education was directed to the bar, he went straight from the University to Hull in 1908 as a secretary to the Norwegian Fisheries Agent for Great Britain, and in that truly maritime place fed his quick intelligence with the matters most congenial to it, acquiring ever increasing information, knowledge and insight into fishing and the fish trade. His apprenticeship in Hull proved very useful when he was called a year later, by the then Fisheries Director, Dr. Hjort, to take up the position of secretary for commercial matters at the Directorate. He worked there for four years until 1913 when his abilities and experience obviously fitted him to fill the vacancy in the position of Norway's

Fisheries Agent for the Continent, in Hamburg. This position required special abilities as an observer and mediator, and extended his knowledge of the fish markets and their possibilities for his country. When on the retirement of Dr. Hjort he was chosen his successor, he brought to the position a wide and varied knowledge of all the commercial aspects of the fisheries. Moreover, he was always a student eager for information and willing to hear the opinions and arguments of others, qualities ever successful in handling situations of conflicting interests and opposing views. His success owed not the least to his ability in obtaining the best possible assistance from his collaborators, who readily gave their service in response to his never-failing recognition and cordial and humane understanding.

Being neither a biologist nor an oceanographer, Mr. Asserson preferred to take no prominent part in the work or discussions of the International Council. Nevertheless, he was a very good listener and gained from his attendance at the Council's meetings a lively interest in fishery research, which he tried his very best to promote in his own country. During his tenure of office both the technological research and the oceanographic and biological investigations have been furthered effectively by large increases in staff and the acquisition of suitable vessels, etc.

His influence on the scientific and technical work, though not touching upon details, was sound and stimulating, and as chairman of the Fishery Research Fund he always kept an open mind for observational and scientific work of a general nature along with the work promising immediate results of a practical nature.

From his early youth Asserson had great historical interests of the practical nature, so to say: he was well acquainted with the history and development of the fisheries and of his people. This gave him a strong sense of the continuity in the life of the people, which always influenced the whole tenor of his service to his land and its folk.

His good-natured personality and ever alert interest in the common tasks and human contacts of life are sorely missed.

O. S.

Die Erwärmung der Arktis.

Von

R. Scherhag,
Reichsamt für Wetterdienst, Berlin.

Problemstellung.

IM Laufe der letzten 20 Jahre sind die arktischen Gebiete von einer Klimaänderung betroffen worden, die nicht nur in meteorologischer Hinsicht erhebliches Interesse beansprucht, sondern von ebenso einschneidenden Änderungen ozeanographischer Natur begleitet ist. Wenn wir hier von Klima*änderung* sprechen, so soll damit nicht gesagt sein, dass es sich um eine dauerhafte Veränderung handelt, sondern es handelt sich dabei höchstwahrscheinlich ebenfalls um einen ebenso periodischen Vorgang wie bei allen anderen Klimaschwankungen, und wir werden im letzten Teil dieser Arbeit auf die wahrscheinliche Periodendauer zurückkommen.

Zunächst wollen wir uns mit den Temperaturänderungen in der Atmo- und Hydrosphäre befassen, den Rückgang der Vereisung im Polargebiet streifen und uns dann den Ursachen dieser Erwärmung zuwenden, die in einer erheblichen Zunahme der atmosphärischen Zirkulation begründet ist.

Die Erhöhung der Lufttemperatur im Polargebiet.

Fasst man die von Helge Petersen[1]) veröffentlichten Abweichungen von Temperatur und Luftdruck an der westgrönländischen Station Jakobshavn (geographische Koordinaten: 69°13′N., 51°2′W.) während der letzten 50 Jahre zu 10-jährigen Mitteln zusammen und bestimmt die Abweichungen vom Normalwert während des Zeitraums von 1876 bis 1925, so erhält man ein eindrucksvolles Bild von der im grönländischen Raum *schon seit 50 Jahren anhaltenden ständigen Temperaturzunahme bei gleichzeitiger Abnahme des Luftdrucks.* In Tabelle 1 sind diese Abweichungen für die eigentlichen Wintermonate der Arktis — Januar bis März und November bis Dezember — zusammengestellt, und wir sehen hier, wie die Milderung der Winter in

[1]) Helge Petersen, Klima der Küsten von Grönland. Handbuch der Klimatologie von W. Köppen und R. Geiger, Band 2, Teil K, Gebr. Borntraeger Berlin 1935.

Tabelle 1.

Temperatur- und Luftdruckabweichungen in Jakobshavn (Westgrönland) im Winter vom Mittel 1876—1925.

Zeitraum	1883—1892	1893—1902	1903—1912	1913—1922	1923—1932
Δt (°C.)	—1·1	—0·7	—0·2	+0·6	+4·0
Δp (mb.)	+0·9	+1·6	—2·7	—0·7	—3·9

Jakobshavn von 1883 bis 1922 bereits stetige Fortschritte gemacht und beinahe den Betrag von 2°C. erreicht hat. Dann ist aber eine weitere ganz *sprunghafte Temperaturerhöhung* festzustellen, sodass der Zeitraum von 1923 bis 1932 in Jakobshavn Winter brachte, die *mehr als* 5°C. wärmer waren als sie dort vor 50 Jahren beobachtet wurden. Dass es sich dabei keineswegs um eine Inhomogenität der Reihe handelt, geht schon aus der gleichzeitigen fortwährenden *Abnahme des Luftdrucks* hervor, die in den letzten 50 Jahren gleichfalls den ausserordentlich hohen Betrag von *mehr als 5mb.* im Mittel der Wintermonate erreicht.

Auf eine wohl noch auffallendere *Temperaturzunahme auf Spitzbergen* mit Beginn des Jahres 1920 hat schon vor einigen Jahren B. J. Birkeland[2]) hingewiesen, und auf die gleiche Erscheinung machte kürzlich O. V. Johansson[3]) aufmerksam. Diese Milderung der Winter auf Spitzbergen hat in den letzten Jahren noch weitere Fortschritte gemacht, sie hat ein solches Ausmass erreicht, dass sie schon auf jeder einzelnen synoptischen Wetterkarte in den Wintermonaten in Erscheinung tritt, wenn man die letzten Jahre mit den Karten vor etwa 20 Jahren vergleicht. Dabei ist ganz besonders auffällig, dass Kältegrade, wie sie vor 25 Jahren dem Durchschnitt entsprachen, jetzt überhaupt im ganzen Winter kaum jemals erreicht werden!

Tabelle 2.

Mittlere Wintertemperaturen auf Spitzbergen.

Zeitraum:	1911-1915	1916-1920	1921-1925	1926-1930	1931-1935
Wintertemperatur (°C.)	—17·6	—17·6	—12·5	—13·9	—8·6

In Tabelle 2 sind die mittleren Wintertemperaturen (worunter wieder die Monate Januar bis März, November und Dezember zusammengefasst sind) auf Spitzbergen während der einzelnen Jahrfünfte, beginnend mit dem Jahre 1911, wo die ständige norwegische Station in Green Harbour eingerichtet wurde, aufgeführt[4]). Mit Beginn

[2]) B. J. Birkeland, Temperaturvariationen auf Spitzbergen. Meteorologische Zeitschrift **47**, S. 234 (1930).

[3]) O. V. Johansson, Die Temperaturverhältnisse Spitzbergens. Annalen der Hydrographie usw. **64**, S. 81 (1936).

[4]) Für den Zeitraum 1911—1930 wurden die Mitteltemperaturen folgender Veröffentlichung entnommen: B. J. Birkeland, Mittel und Extreme der Lufttemperatur. Geofysiske Publikasjoner Band 14, No. 1. Die Werte für 1931—1935 wurden der unter 10) zitierten Arbeit entnommen.

des dritten Jahrzehnts ist eine plötzliche Milderung der Winter auf Spitzbergen um etwa 5°C. erfolgt, die im Zeitraum 1931—1935 fast 10° erreicht hat. Dabei ist die durch die im Jahre 1930 erfolgte Verlegung der Station nach Lonyearbeen eingetretene auf Grund von Vergleichsmessungen[5]) zu etwa 1·0°C. festgestellte Temperaturerhöhung bereits berücksichtigt, sodass die Reihe völlig homogen ist. Eine derartige Temperaturänderung, wie wir sie auf Spitzbergen erleben, muss man zu den grössten bekannten Klimaänderungen zählen!

Derartige Klimaänderungen, wie wir sie auf Spitzbergen und an der grönländischen Westküste beobachten, können sich natürlich nicht auf ein kleines Gebiet beschränken, sondern müssen weltumspannend sein. In der Tat fehlt es nicht an Untersuchungen, die eine ähnliche Temperaturerhöhung in anderen Zonen zum Gegenstand haben, nur ist das Ausmass der Erwärmung meist wesentlich geringer. So hat J. B. Kincer[6]) für viele Orte der Erde eine ständige Temperaturzunahme von säkularem Ausmass nachgewiesen, und für die Britischen Inseln haben die gleiche Erscheinung A. E. M. Geddes[7]) und C. E. P. Brooks[8]) gezeigt.

Eine eingehende Untersuchung der Änderung der Temperatur auf der gesamten Nordhalbkugel im Jahrzehnt 1921 bis 1930[9]) hat zu dem Ergebnis geführt, dass tatsächlich *der grösste Teil der Nordhalbkugel im Jahrzehnt 1921 bis 1930 wesentlich zu warm war.* Ein schmaler Streifen, wo die Temperatur gesunken ist, fällt im allgemeinen mit dem Rossbreitengürtel zusammen, und ausserdem zeichnet sich nur die an der südlichen Hudsonbay liegende Station Moose Factory durch eine negative Abweichung aus. Im übrigen weisen sämtliche Stationen nördlich vom 55. Breitengrad Erwärmung auf, die mit Annäherung an den Pol immer mehr zunimmt und ihren Maximalbetrag an der grönländischen Westküste mit einem Anstieg von 2 Grad erreicht. Noch grösser ist die Erwärmung bei Spitzbergen, doch beginnt die dortige Temperaturreihe erst im Jahre 1912, und der Zeitraum 1921—1930 konnte lediglich mit der kurzen Periode 1912—1920 verglichen werden.

Die Linien gleicher Temperaturzunahme ordnen sich fast genau ringförmig um den Pol an, nach Süden zu reicht das Erwärmungsgebiet bis zum Golf von Mexiko und bis nach Mittelsibirien, umfasst den grössten Teil Europas und ebenfalls das gesamte Mittelmeergebiet sowie Nordafrika.

Fasst man lediglich die Temperaturänderung in den Wintermonaten November bis März ins Auge, so ist das Bild ähnlich, wie wir es für das Jahresmittel beschrieben haben, die Temperaturerhöhung in den

[5]) Siehe Jahrbuch des Norwegischen Meteorologischen Instituts für 1932.

[6]) J. B. Kincer, Is Our Climate Changing? A Study of Long-Time Temperature Trends. Monthly Weather Review **61**, S. 251 (1933).

[7]) A. E. M. Geddes, Temperature Trend at Aberdeen from 1870 to 1932. Quarterly Journal Roy. Met. Soc. **61**, S. 347 (1935).

[8]) C. E. P. Brooks, The Change of Climate in the British Isles. The Meteorological Magazine **70**, S. 153 (1935).

[9]) R. Scherhag, Die Zunahme der atmosphärischen Zirkulation in den letzten 25 Jahren. Annalen der Hydrographie usw. **64**, S. 397 (1936).

polaren Gebieten ist aber noch wesentlich stärker ausgeprägt. Nördlich des 60. Breitengrades überschreitet die im Winter im letzten Jahrzehnt eingetretene Temperaturerhöhung allgemein 1° und erreicht ihr Maximum im Raume der Ostgrönlandsee. Die Gebiete mit Temperaturabnahme treten völlig zurück und beschränken sich auf das mittlere Asien, den Westteil des Mittelmeeres, den Atlantischen Ozean zwischen den Azoren und Bermuda und einen schmalen Gebietsstreifen längs des Felsengebirges.

Wir wollen uns nach diesem kurzen Überblick über die auf der Nordhalbkugel seit etwa 1920 eingetretene Temperaturerhöhung den gleichzeitigen ozeanographischen Folgen zuwenden und beginnen mit einer Betrachtung der Eisverhältnisse im Nordpolargebiet.

Der Rückgang der Vereisung in der Arktis.

Die Erhöhung der Lufttemperatur in der Arktis ist, wie nicht anders zu erwarten, mit einem erheblichen Rückgang der Vereisung und einem Zurückziehen der Packeisgrenze verbunden. In Tabelle 3 sind

Tabelle 3.

Mittlere Abweichung der Eisgrenze (in km.) im Ostspitzbergenmeer (30° bis 50° Ostlänge) im Spätsommer.

(Südl. Abw. +, nördl. Abw. —).

Jahr	Abweichung	Jahr	Abweichung	Jahr	Abweichung
1898	—140	1911	0	1923	—210
1899	—100	1912	+110	1924	—100
1900	— 50	1913	+160	1925	—170
1901	— 60	1914	+120	1926	— 50
1902	+ 40	1915	+ 30	1927	— 10
1903	+ 80	1916	+320	1928	— 70
1904	+ 10	1917	+140	1929	— 10
1905	—110	1918	+100	1930	—290
1906	—150	1919	— 30	1931	—270
1907	—240	1920	—140	1932	—100
1908	—230	1921	—120	1933	—280
1909	+ 70	1922	—270	1934	—180
1910	+ 80				

die an anderer Stelle bildlich[10]) wiedergegebenen mittleren Lagen der Eisgrenze während des Spätsommers (August) im Ostspitzbergenmeer zusammengestellt. Für die einzelnen Jahre wurde dabei die Packeisgrenze an Hand der Dänischen Eiskarten[11]) für die Meridiane 30°, 40° und 50° Ostlänge bestimmt und daraus die mittlere meridionale Abweichung von der durchschnittlichen Lage während der Epoche 1898

[10]) R. Scherhag, Eine bemerkenswerte Klimaänderung über Nordeuropa. Annalen der Hydrographie usw. **64**, S. 96 (1936).

[11]) Isforholdene i de arktiske Have. Publikationer fra det Danske Meteorologiske Institut (1898—1934).

bis 1922 bestimmt. Wenn ausnahmsweise für August keine Eisbeobachtungen vorlagen, wurde der Juli und in einigen wenigen Fällen auch die Lage der Eisgrenze im Juni zugrunde gelegt.

Aus Tabelle 3 entnehmen wir, dass die grösste Vereisung des Ostspitzbergenmeeres im Jahre 1916 beobachtet wurde, und zu gleicher Zeit folgte der ganz extrem kalte Winter 1916/17 zu Spitzbergen, der dort für die Monate November bis März ein Temperaturmittel von —22·8° zustande brachte, 14° niedriger als im Winter 1933/34, wo das Mittel der gleichen Monate nur —8·7° betrug! Die damalige starke Vereisung des Ostspitzbergenmeeres wirkte sich bis nach Mitteleuropa hin aus und führte hier zu einem gleichfalls recht strengen Winter.

Ein Jahr später, im Jahre 1918, wurde nun zum letzten Male eine südliche Abweichung der Eisgrenze im Ostspitzbergenmeer beobachtet, seitdem hat die Eisgrenze die Mittellage im südlicher Richtung überhaupt nicht mehr überschritten! Zusammen mit dem gewaltigen Rückzug der Eisgrenze bis 1922 erfolgte eine rapide Zunahme der Lufttemperatur, und der dann bis zum Zeitraum 1927/1929 erfolgende erneute Vorstoss der Eisbarriere, mit dem der extrem kalte europäische Winter 1928/29 gekoppelt war, vermochte nicht mehr die Mittellage zu überschreiten, und seitdem hat sich die Eisgrenze sogar wieder 200 bis 300 km. nordwärts zurückgezogen.

Im ganzen lassen sich drei Eisvorstösse erkennen, die in einem Abstand von 12 bis 13 Jahren aufeinander folgten. Bemerkenswert ist aber, dass der letzte Vorstoss nicht einmal mehr über die mittlere Lage hinaus reichte, seit dem Jahre 1919 die Eisgrenze also ständig nördlich der Mittellinie liegt und den einzelnen periodischen Vorstössen von etwa 12 Jahren also eine wesentlich längere Schwankung überlagert ist. Der ständige Rückgang der Vereisung geht parallel mit der Erhöhung der Lufttemperatur. Wie die Lage der Eisgrenze mit der Lufttemperatur in Spitzbergen auf das engste gekoppelt ist, erkennt man am besten durch einen Vergleich beider Werte für die einzelnen Jahre, wie er in Fig. 1 der unter Fussnote 10 zitierten Arbeit abgebildet ist. Diese enge Übereinstimmung ist natürlich eine Folge davon, dass Spitzbergen gerade an der Eiskante liegt und geringe Verschiebungen in nördlicher Richtung schon bewirken, dass die Nordwinde erst offenes Wasser überwehen, bevor sie Spitzbergen erreichen und dann äusserst rasch erwärmt werden. Aus diesem Grunde muss die zur Diskussion stehende Klimaänderung natürlich auch an der Eiskante selbst ihren grössten Betrag erreichen.

Wir wollen uns nun der gleichzeitigen erheblichen Erhöhung der Wassertemperatur in der Arktis zuwenden.

Die Erhöhung der Wassertemperatur in der Arktis.

Über die ungewöhnliche Erhöhung, die die Wassertemperatur in den arktischen Gebieten in den letzten Jahren erfahren hat, ist ein

eingehender Aufsatz von J. Schokalsky[12]) erschienen, dem wir die folgenden Tatsachen entnehmen:

Durch die intensive Erforschung der Barentssee, wohin das Moskauer Ozeanographische Institut in den letzten Jahren allein mehr als 100 Expeditionen entsandt hat, von denen jede etwa zwei Monate dauerte und die in den letzten Jahren auch auf die Ostgrönlandsee ausgedehnt wurden, ist eine erhebliche Erhöhung der Wassertemperatur einwandfrei nachgewiesen worden. Während Nansen auf der "Fram"- Expedition (um 1895) im Polarmeer eine Deckschicht von 200 bis 250m. Tiefe mit einer Temperatur von —1·0 bis —1·9° feststellte, wurden von der "Elding" im Jahre 1927 zwischen Franz Josephsland und Nowaja Semlja in 100m. Tiefe *+1·1°* gemessen, und der Eisbrecher "Krassin" bestätigte diese Beobachtung im folgenden Jahre, ebenso Sverdrup auf der "Nautilus"-Expedition. Der Temperaturanstieg beträgt danach in 100 bis 200m. Tiefe im Laufe der letzten 30 Jahre 2 bis 3°!

Im Jahre 1929 wurde von den dem Moskauer Geographischen Institut gehörenden Schiffen "Sedoff" und "Persée" an der gleichen Stelle, die "Makazoff" für seine Beobachtungen im Jahre 1901 wählte, die Null-Grad-Isotherme schon in einer Tiefe von 125 statt 200m. gefunden. 1931 fand die "Persée" diese Isotherme in der gleichen Gegend bereits in 75m. Tiefe und die "Lomohosoff" etwas weiter östlich sogar schon zwischen 25 und 40m. Tiefe. Darunter stieg die Temperatur auf +1·6° an. Ähnliche Verhältnisse wurden 1932 zwischen Franz Josephsland und Nowaja Semlja angetroffen und 1934 bestätigt. Schliesslich erwähnt Schokalsky, dass die Erwärmung des Polargebiets im Jahre 1921 begonnen habe und schreibt[13]): "*Der Zweig des Nordatlantischen Stromes, der in den Arktischen Ozean am Rand des Kontinentalschelfs bei Spitzbergen eintritt, hat an Mächtigkeit so wesentlich zugenommen, dass die Deckschicht kalten Wassers, die zu Nansens Zeit 200m. dick war, jetzt auf weniger als 100m. reduziert worden ist.*" Schokalsky[14]) fasst seine wichtigen Ausführungen am Schluss in dem Satz zusammen: "*Wir entdeckten, dass das Nördliche Eismeer zur Zeit einer Periode steigender Temperatur unterliegt.*"

Wir werden im folgenden Abschnitt sehen, dass die Erhöhung der Wassertemperatur nicht allein auf die Arktis beschränkt ist.

Wassertemperaturänderungen in anderen Meeresteilen.

Untersuchungen über Änderungen der Oberflächentemperatur des Meeres liegen bisher nur wenige vor, und die Beobachtungszeiten sind meist nur kurz. Im Jahre 1934 erschien erstmalig eine auf umfangreichem Beobachtungsmaterial beruhende Zusammenstellung von

[12]) J. Schokalsky, Recent Russian Researches in the Arctic Sea and in the Mountains of Central Asia. The Scottish Geographical Magazine **52**, Nr. 2 (März 1936).

[13]) l.c. S. 76.

[14]) l.c. S. 79.

G. Slocum[15]) über die Wassertemperaturen in der Jucatan-Strasse während des Zeitraums von 1912 bis 1933, und im folgenden Jahr folgten weitere Veröffentlichungen für die gleiche Periode für den östlichen [16]), nordwestlichen [17]), nördlichen [18]) und südwestlichen Teil des Golfs von Mexiko[19]) und für den Zeitraum von 1920—1933 auch für die Caribische See[20]). Diese Zusammenstellungen wurden noch

Tabelle 4.

Wassertemperaturen im Ursprungsgebiet des Golfstroms (°C.).

Zone	1912/18	1919/25	1926/33	Änderung	1912/21	1922/33	Änderung
1. 15—20°N. 80—85°W.	—	27·00	27·41	—	—	—	—
2. 21—23°N. 84—87°W.	26·77	26·71	27·03	+0·26	26·66	26·94	+0·28
3. 23—24°N. 82—84°W.	26·31	26·56	26·84	+0·53	26·33	26·78	+0·45
4. 25—30°N. 79—80°W.	25·90	26·11	26·33	+0·43	25·89	26·28	+0·39
5. 25—26°N. 84—86°W.	25·50	25·78	26·00	+0·50	25·61	25·94	+0·33
6. 21—25°N. 90—94°W.	25·24	26·09	25·88	+0·64	25·66	25·89	+0·23
7. 26—28°N. 86—89°W.	25·33	25·50	25·58	+0·25	25·39	25·53	+0·14
8. 27—29°N. 90—93°W.	23·83	24·27	24·22	+0·39	23·94	24·28	+0·34
Mittel Zone 2—8	25·55	25·86	25·97	+0·42	25·64	25·95	+0·31

[15]) G. Slocum, Sea-Surface Temperature Summary for the Yucatan Channel 1912—1933. Monthly Weather Review **62**, S. 425 (1934).

[16]) G. Slocum, Sea-Surface Temperature Summary for the East-Central Gulf of Mexico, 1912—1933. Monthly Weather Review **63**, S. 71 (1935).

[17]) G. Slocum, Sea-Surface Temperature Summary for the North-west Gulf of Mexico 1912—1933. Monthly Weather Review **63**, S. 147 (1935).

[18]) G. Slocum, Sea-Surface Temperature Summary for the North-Central Gulf of Mexico, 1912—1933. Monthly Weather Review **63**, S. 174 (1935).

[19]) G. Slocum, Sea-Surface Temperature Summary for the South-west Gulf of Mexico, 1912—1933. Monthly Weather Review **63**, S. 204 (1935).

[20]) G. Slocum, Sea-Surface Temperature for the Caribbean Sea, 1920—1933. Monthly Weather Review **63**, S. 113 (1935).

ergänzt für die gesamte Periode von 1912 an für den südwestlichen[21]) und äusseren Teil der Florida-Strasse[22]), und in Tabelle 4 sind diese gesamten Ergebnisse für die einzelnen Gebiete, die im allgemeinen jeweils auf mehr als 1000 Einzelmessungen beruhen, für verschiedene Epochen zusammengestellt.

In den ersten drei Zeilen ist der gesamte Zeitraum in die beiden siebenjährigen Abschnitte von 1912 bis 1918, 1919 bis 1925 und den achtjährigen Zeitraum von 1926 bis 1933 aufgeteilt worden, und wir sehen, dass von den acht verschiedenen Zonen in fünf Gebieten eine *ständige Zunahme der Jahrestemperatur des Oberflächenwassers* festzustellen ist. *Im Zeitraum von 1926 bis 1933 war das Meer im gesamten Ursprungsgebiet des Golfstroms merklich wärmer als während der Periode von 1912 bis 1918,* die Einzelwerte schwanken zwischen einer Erhöhung von $+0{\cdot}25°$ und $+0{\cdot}64°$, und *im Mittel beträgt die Temperaturerhöhung in der letzten Periode* $+0{\cdot}42°$.

Wir haben bei der Besprechung der Erhöhung der Temperatur auf Spitzbergen und an der grönländischen Westküste sowohl wie bei dem Rückgang der Vereisung im Ostspitzbergenmeer bemerkt, dass die entscheidende Erwärmung um die Wende vom zweiten zum dritten Jahrzehnt eingetreten ist. In der 6. und 7. Kolonne der Tabelle 4 ist entsprechend der Zeitraum 1912 bis 1933 in zwei Abschnitte von 1912—1921 bezw. 1922—1933 aufgeteilt worden, und wir erkennen hier, dass die *letztere Periode im gesamten Gebiet wärmer war als der vorhergehende Zeitraum, im Mittel lag die Meerestemperatur im Bereich des Golfs von Mexiko und der Florida-Strasse um* $0{\cdot}31°$ *höher.*

Untersucht man die einzelnen Jahre, so findet man, dass die eigentliche Erwärmung mit dem Jahre 1922 begonnen hat, also fast zur gleichen Zeit, wie die Milderung der Winter auf Spitzbergen eintrat.

Eine Erhöhung der Wassertemperatur um $0{\cdot}4°$ innerhalb von 15 Jahren in einem derart ausgedehnten Meeresgebiet muss als sehr beträchtlich angesehen werden, und da die untersuchte Zone mit dem Ursprungsgebiet des Golfstroms zusammenfällt, können wir erwarten, dass eine ähnliche Erhöhung der Temperatur des Golfstroms auch an der europäischen Westküste zu beobachten sein muss.

Für den Englischen Kanal liegt eine eingehende Bearbeitung des Salzgehalts und der Temperatur von J. R. Lumby[23]) vor, worin auch die mittleren Oberflächentemperaturen für die Jahre 1903—1927[24]) mitgeteilt werden. Diese wurden in ähnlicher Weise wie für das Ursprungsgebiet des Golfstroms in drei gleich lange Perioden unterteilt (Tab. 5), und es ergibt sich dabei für den Zeitraum von 1903 bis

[21]) G. Slocum, Sea-Surface Temperature Summary for the South-western Portion of the Florida Straits, 1912—1933. Monthly Weather Review **64**, S. 310 (1936).

[22]) G. Slocum, Sea-Surface Temperature for the Outer Florida Strait, 1912—1933. Monthly Weather Review **64**, S. 279 (1936).

[23]) J. R. Lumby, Salinity and Temperature of the English Channel. Ministry of Agriculture and Fisheries; Fishery Investigations, Series II, Vol. XIV, No. 3.

[24]) *l.c.* S. 53, Fig. 8.

Tabelle 5.

Wassertemperaturen im Englischen Kanal (°C.).

1903—1911	1912—1919	1920—1927	Änderung
11·7	11·8	12·1	+0·4

1919 annähernde Konstanz der Wassertemperatur, während seitdem *auch im Englischen Kanal eine Zunahme von +0·4° eingetreten ist.* Also auch hier finden wir *mit Beginn des 3. Jahrzehnts eine plötzliche Zunahme der Wassertemperatur zur gleichen Zeit, wo die Erwärmung im Polargebiet ein phänomenales Ausmass annimmt.*

Dass im übrigen die Beziehung zwischen der Wassertemperatur im Englischen Kanal und der Lage der Eisgrenze im Meeresgebiet zwischen Spitzbergen und Nowaja Semlja eine recht enge ist, zeigt ein Vergleich der in Tabelle 3 mitgeteilten Lagen der Eisgrenze mit der gleichzeitigen Oberflächentemperatur im Englischen Kanal[24]), welchen Hinweis ich einer freundlichen brieflichen Mitteilung von Herrn Dr. J. N. Carruthers verdanke.

Da man für den inneren Teil des Englischen Kanals eine zu starke Rückwirkung der Temperatur auf dem europäischen Festland auf die Wasserwärme befürchten kann, habe ich versucht, die mittleren Temperaturen für den westlichsten Teil des Kanals allein auf Grund der von Lumby mitgeteilten Originalwerte[25]) zu berechnen, und in der Tat erhält man auch hierfür (Tab. 6) zwischen dem Zeitraum 1910—1917 und 1920—1927 einen Temperaturanstieg von etwas über 0·2°, doch tritt die Temperaturerhöhung nicht deutlicher in Erscheinung, als wenn man die Mittel für den gesamten Teil des Kanals heranzieht. Wahrscheinlich sind die Beobachtungen in diesem kleinen Gebiet doch zu spärlich, wo es sich vielfach nur um ein paar Messungen im ganzen Jahre handelt, um daraus weitergehende Schlüsse zu ziehen. Das amerikanische Beobachtungsmaterial ist demgegenüber wesentlich reichhaltiger.

Tabelle 6.

Wassertemperaturen am Westeingang des Englischen Kanals (°C.).

1903—1909	1910—1917	1920—1927
12·22	12·13	12·35

Irgendwelche weiter zurück liegenden Messungen der Golfstromtemperatur stehen uns nicht zur Verfügung. Wir können aber annehmen, dass die weit in den Ozean vorgeschobenen norwegischen Inselstationen, bei vorherrschenden südwestlichen Winden, einen recht guten Indikator für die Änderungen der Oberflächentemperatur im Bereich des Nordatlantischen Stromes abgeben, und deshalb werden in Tabelle 7 die mittleren Jahrestemperaturen für sämtliche Dezennien beginnend mit 1866 für drei der am weitesten westwärts vorgeschobenen norwegischen Stationen mitgeteilt[26]): Röst auf den Lofoten in 67°30′N.,

[25]) *l.c.* S. 64, Region 1—10.

[26]) Die Mittelwerte wurden auf Grund der von B. J. Birkeland (siehe Fussnote 4) veröffentlichten Temperaturreihen berechnet.

Tabelle 7.

Lufttemperaturen an der norwegischen Westküste (°C.).

Station	Röst	Ona	Utsira	Mittel
1866—1875	(4·5)	6·4	6·9	5·9
1876—1885	4·8	6·6	6·9	6·1
1886—1895	4·8	6·7	7·0	6·2
1896—1905	4·6	6·8	7·1	6·2
1906—1915	4·8	7·0	7·4	6·4
1916—1925	5·1	7·0	7·1	6·4
1926—1935	5·7	7·1	7·5	6·8
1931—1935	5·8	7·2	7·7	6·9

12°4′E., Ona in 62°52′N., 6°33′E. und Utsira in der nördlichen Nordsee auf 59°18′N., 4°53′E.

Röst ist zweifellos die am ungestörtesten den atlantischen Luftströmen ausgesetzte Station, und damit in Übereinstimmung *zeigt sich hier eine zu Beginn dieses Jahrhunderts einsetzende Erhöhung der Lufttemperatur am deutlichsten: Sie überschreitet im Jahresmittel 1°.* Die Reihe von Ona zeigt eine *ununterbrochene Temperaturerhöhung schon seit den sechziger Jahren des vorigen Jahrhunderts, ebenso Utsira,* doch ist der gesamte Betrag etwas geringer und beträgt nicht viel mehr als einen halben Grad.

Mittelt man die Temperaturen der drei Stationen (letzte Spalte der Tab. 7), so sieht man, dass *eine Erhöhung der Meerestemperatur längs der norwegischen Westküste schon seit Beginn regulärer meteorologischer Beobachtungen im Jahre 1870 wahrscheinlich ist, dass die Temperaturerhöhung aber erst im letzten Jahrzehnt sprunghafte Fortschritte gemacht hat.*

Unsere Bemerkungen im 2. Abschnitt über die Erwärmung der Landgebiete können wir also jetzt dahin erweitern, dass auch *auf grossen Gebieten des Nordatlantischen Ozeans eine Erhöhung der Wassertemperatur* eingetreten ist. Dass im Gegensatz hierzu die Temperatur auf einzelnen Inselstationen etwas abgenommen hat, steht in gewissem Widerspruch und bedarf noch der Klärung, zumal diese Abkühlung auch schon im Jahrzehnt 1911—1920 festzustellen war und die Ursache von A. Wagner[27]) in einer Erhöhung der Turbulenz vermutet wurde.

Wir können jetzt dazu übergehen, uns mit der Ursache der Erwärmung zu befassen, die in einer erheblichen Zunahme der atmosphärischen Zirkulation begründet ist.

Über die Ursache der Erwärmung.

Wenn wir der Ursache für die Erhöhung der Temperaturen in der Arktis nachgehen, so müssen wir dafür die Zunahme der atmosphärischen Zirkulation verantwortlich machen. Bereits vor 8 Jahren ist eine

[27]) A. Wagner, Untersuchungen der Schwankungen der allgemeinen Zirkulation. Geografiska Annaler, **9**, S. 33 (1929). Derselbe: Neuere Untersuchungen über die Schwankungen der allgemeinen Zirkulation. Meteorolog. Zeitschrift. 1929, S. 483.

eingehende Untersuchung von A. Wagner[27]) über die Zirkulationsänderung im Jahrzehnt 1911 bis 1920 gegenüber der Periode 1886 bis 1895 erschienen mit dem Ergebnis, dass die Zirkulation seit 1886 eine wesentliche Zunahme erfahren hat. In meiner bereits zitierten Arbeit[9]) wird darüber hinausgehend nachgewiesen, dass *die atmosphärische Zirkulation im Jahrzehnt 1921 bis 1930 eine noch weitere Steigerung erfahren und ganz wesentlich zugenommen hat,* wenn man sie mit der Grösse der Zirkulation im Mittel der Zeit vor 1920 vergleicht, soweit die einzelnen Beobachtungsreihen zurückreichen.

Betrachtet man das Jahresmittel des Luftdrucks, so geht mit überzeugender Deutlichkeit daraus hervor, dass der *Luftdruck im Jahrzehnt 1921 bis 1930 in der polaren Tiefdruckrinne durchweg erniedrigt, im Rossbreitengürtel dagegen erhöht war. Die stärkste Druckabnahme finden wir mit —2·1mb. in Jakobshavn an der grönländischen Westküste,* um den gleichen Betrag scheint sich das Alëuten-Tief verstärkt zu haben. Die *Druckzunahme* erreicht ihren *grössten Betrag auf Madeira und Bermuda* mit einem *Anstieg von +1·5 bezw. +1·9mb.* Man sieht also: *die Westwinddrift hat zwischen 35 und 65° Breite auf der ganzen Nordhalbkugel erheblich zugenommen.*

Untersucht man lediglich die Druckänderung im *Winter,* wobei die Monate November bis März zusammengefasst wurden, so ist die Zunahme der Zirkulation im Jahrzehnt 1921 bis 1930 noch weit deutlicher. Die *Druckerniedrigung überschreitet* zu dieser Zeit an der *grönländischen Westküste allgemein 2mb. und erreicht in Jakobshavn mehr als 3mb.*

Am eindrucksvollsten ist diese Änderung des Druckgefälles aber, wenn man lediglich den Monat Januar heranzieht. *Um mehr als 4mb. war der Januar-Luftdruck im letzten Jahrzehnt südwestlich von Island und über der Davis-Strasse erniedrigt. Die gleiche erhebliche Energiezunahme weist das Alëuten-Tief auf,* und auf diese Weise ergibt sich eine *Druckverminderung über dem gesamten Polargebiet mit den Zentren in den beiden zyklonalen Aktionszentren der Nordhemisphäre.*

Der südlich an diese Zone negativer Anomalie anschliessende *Ring erhöhten Luftdrucks erreicht jetzt Maximalwerte bei Madeira mit +3·1mb., über dem Ostpazifik mit mehr als 2mb. und im mittelsibirischen Hoch bei Taschkent sogar +6·3mb.*

Das eindrucksvollste Ergebnis dieser Untersuchung der Druckänderungen ist aber: *Die Gebiete grösster Druckänderungen fallen alle nahe zusammen mit den Kernen der nordhemisphärischen Aktionszentren, die sämtlich verstärkt, also die Zyklonen vertieft und der Luftdruck in den Hochdruckgebieten erhöht, sind. Die Druckabnahme zwischen dem 30. und 70. Parallelkreis war während des Jahrzehnts 1921—1930 gegenüber dem Zeitraum von 1850 bis 1900 im Jahresmittel um 30%, im Januar um etwa 50% grösser.*

Bezüglich weiterer Einzelheiten muss auf die Originalarbeit verwiesen werden, es sei hier lediglich noch darauf hingewiesen, dass in gleicher Weise wie es A. Wagner[27]) unternommen hat, auch die Druck- und Temperaturänderungen auf der ganzen Erde untersucht

wurden und sich hierbei eine fast völlige Übereinstimmung mit den Ergebnissen Wagners ergab. Die in den Rossbreiten erkennbare Druckzunahme erstreckt sich über den Äquator hinaus bis zum südlichen Rossbreitenhoch, und in dieses grosse Gebiet einheitlicher Druckerhöhung sind nur einige schmale Zonen mit Druckabnahme eingeschaltet über dem äquatorialen Amerika, dem Persischen Golf und dem östlichen Teil des Indischen Ozeans. Südlich des 30. Breitengrades zeigt sich auch auf der Südhalbkugel mit Ausnahme von Südamerika, soweit es die allerdings spärlichen Reihen von Südafrika, Südaustralien und Neuseeland zu übersehen gestatten, allgemeine Druckabnahme, sodass es den Anschein hat, dass auch auf der Südhalbkugel die Zirkulation ebenso zugenommen hat.

Wir wollen uns abschliessend dem Problem zuwenden, ob wir schon irgend eine Aussage über die Periode dieser Zirkulationsschwankung und der Erhöhung der Lufttemperatur machen können.

Über die Periode der Zirkulationsschwankung.

Fasst man den Zeitpunkt der Temperaturänderung für verschiedene Erdzonen ins Auge, so wird man auf einen charakteristischen Unterschied im Eintritt der rapiden Erwärmung aufmerksam: Im Polargebiet selbst ist die eigentliche Erwärmung nämlich erst zu Beginn des dritten Jahrzehnts erfolgt, wie sowohl unsere Reihe der Temperaturabweichungen in Jakobshavn (Tab. 1) zeigt und es noch deutlicher im Temperaturverlauf auf Spitzbergen (Tab. 2) ausgeprägt ist. Gerade das zweite Jahrzehnt war über grossen Teilen des Polargebiets besonders kalt, sodass A. Wagner für die Arktis im Jahrzehnt 1911—1920 sogar noch eine etwas niedrigere Temperatur erhielt als für den Zeitraum von 1886 bis 1895. Über Mittel- und Westeuropa ist die eigentliche Milderung der Winter aber schon zu Anfang dieses Jahrhunderts erfolgt, also wesentlich früher.

Dieses Ergebnis steht allerdings im Widerspruch zu den Schlussfolgerungen von A. Wagner[28]), dass die Milderung der Winter zuerst im Norden begonnen habe. Unter "Norden" versteht Wagner aber hauptsächlich skandinavische Orte, und es ist daher durchaus möglich, dass sich die Verstärkung der atmosphärischen Zirkulation zuerst in den innerhalb der eigentlichen Zyklonenbahnen liegenden Orten auswirkte und erst mit weiterer Vergrösserung der Westwinddrift immer weiter nach Süden *und* Norden übergriff. Über diesen Problemkreis ist die Diskussion wohl noch lange nicht abgeschlossen, und es bleibt auch in diesem Zusammenhang noch zu klären, inwiefern trotz der Zunahme der Zirkulation gleichzeitig die Untersuchungen von S. Evjen[29]) ergeben haben, dass die barometrische Unruhe in ganz Norwegen gerade abgenommen hat.

[28]) A. Wagner, Untersuchung der säkularen Änderung der Jahresschwankung der Temperatur in Europa. Gerlands Beitr. z. Geophysik **20**, S. 134 (1928).

[29]) S. Evjen, Beitrag zur Kenntnis der barometrischen Unruhe. Meteorolog. Zeitschrift **47**, S. 107 (1930).

Fest steht jedenfalls, dass in der Arktis die hauptsächlichste Temperaturerhöhung erst mit Beginn des Jahres 1920 eingetreten ist, später als in Mitteleuropa. Vergleicht man weiter die Lage des Gebiets negativer Druckanomalie im Jahrzehnt 1911—1920 mit dem folgenden Dezennium, so sieht man, dass dieses sich nordwärts vom Atlantischen Ozean zur Westküste Grönlands verlagert hat. Auch wurde festgestellt[9]), dass die Zone stärkster Druckabnahme von 1850—1900 noch weiter südlich lag als von 1881—1920, sodass eine *nördliche Verlagerung der Zone niedrigsten Luftdrucks im Laufe der letzten 50 Jahre angenommen werden muss.*

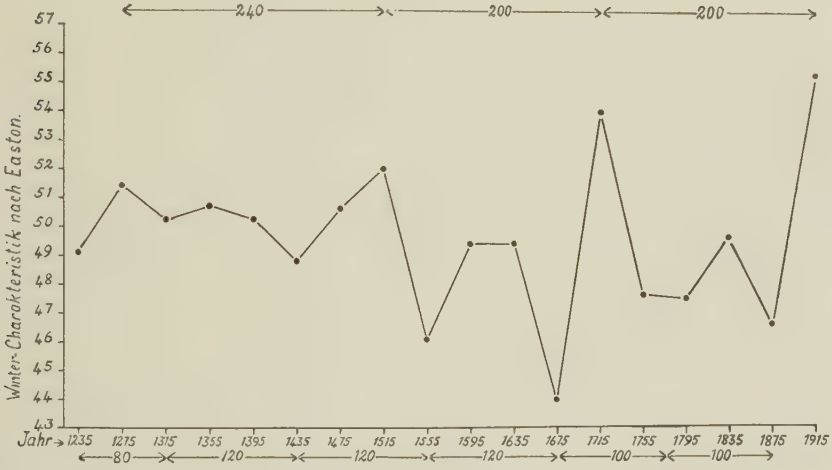


Fig. 1. Die Koeffizienten der Winter in Westeuropa, zusammengefasst zu je 40-jährigen Zeiträumen von 1215 bis 1935.

Um welche Periode handelt es sich nun bei dieser Zirkulationsänderung? Sicherlich ist sie nicht identisch mit irgendeiner kurzperiodischen Klimaschwankung wie etwa der 16-jährigen Periode. Einer brieflichen Mitteilung von Herrn Prof. W. Köppen verdanke ich einen Hinweis, dass es sich wahrscheinlich um eine etwa 220-jährige Periode handeln könnte, die Köppen auf Grund der von C. Easton[30]) berechneten Koeffizienten für die westeuropäischen Winter herausgefunden hat. Ich habe die mittleren Koeffizienten daraufhin für je 40 Jahre zusammengefasst, beginnend mit 1235, und das in Fig. 1[31]) dargestellte Ergebnis ist recht eindrucksvoll: Perioden wärmster Winter findet man für den Zeitraum um 1275, 1515, 1715 und (1915), also nach je 240, 200 und (200) Jahren, im Mittel also

[30]) C. Easton, Les Hivers dans L'Europe Occidentale. Leyden 1928.

[31]) Easton hat normalen Wintern den Koeffizienten 50 beigelegt, extrem kalte Winter werden mit 0, besonders warme mit 100 bezeichnet. Für den Zeitraum 1896—1916 erhält Easton den mittleren Koeffizienten 56·6; die Werte bis 1935 wurden vom Verfasser nach den Temperaturabweichungen in Deutschland näherungsweise bestimmt.

in einem Abstand von rund 220 Jahren. Sekundäre Maxima zeigen sich ausserdem zu den Zwischenterminen, und bei den kalten Wintern beträgt der Abstand der Zeiten grösster Häufung 80, 120, 120, 120, 100, 100, also im Mittel 110 Jahre. Die jetzige Periode milder Winter würde also etwa derjenigen zu Anfang des 18. Jahrhunderts entsprechen, wobei allerdings nicht verschwiegen werden soll, dass die augenblickliche Temperaturerhöhung ganz besonders auffallend ist.

Das Resultat einer 220-jährigen Periode der Zirkulationsschwankung, mit der die Wintertemperatur gekoppelt sein muss, führt uns zu dem Ergebnis, dass die Milderung ihren Höhepunkt jetzt erreicht, wenn nicht bereits überschritten haben muss. Zu dem gleichen Ergebnis sind auch u.a. A. Peppler[32]), F. Steinhäuser[33]), A. E. M. Geddes[7]) und P. Gillette[34]) gekommen, und der Verlauf der letzten Winter hat ebenso Anzeichen dafür erbracht[35]), dass die Zirkulationssteigerung ihren Höhepunkt überschritten hat, wozu vor allem die, wenn auch kurze, aber in solcher Intensität schon viele Jahre nicht mehr beobachtete Kälteperiode im Gebiet der Ostgrönlandsee vom 23. bis 25. Februar 1937 beiträgt, die auf Jan Mayen sogar das bisherige absolute Temperaturminimum gebracht hat. Für die Erschliessung der Nordostpassage wäre eine Abnahme der Zirkulation natürlich eine ganz wesentliche Erschwerung, mit der aber mit grosser Wahrscheinlichkeit gerechnet werden muss.

Summary.

The greater mildness of winters observable in the temperate zone during the last hundred years, accompanied by an increase in atmospheric circulation, has, during the last fifteen years, led to an extraordinary rise in temperature in the arctic regions, which in its turn has been accompanied by a corresponding retreat of the ice and a higher temperature in the sea. Just as, in the region from which the Gulf Stream springs, measurements of water temperature indicate a rise of about 0·5°C. in the last ten years, there has also been found a like increase in surface temperature in the English Channel. Fifty-year series of temperatures from off-lying Norwegian coastal stations clearly manifest a similar warming, and it is therefore indubitable that *the transport of the warm water of the Gulf Stream from Florida to its entry into the arctic has increased to a noteworthy extent.* In this respect it appears to be a question of a secular period in the variation of atmospheric circulation of some 225 years duration, which seems at this juncture to have attained its maximum.

[32]) A. Peppler, Stehen wir am Beginn einer kontinentaleren Klimaepoche? Zeitschr. f. angewandte Meteorologie **53**, S. 37 (1936).

[33]) F. Steinhäuser, Wie ändert sich unser Klima? Meteorolog. Zeitschr. **52**, S. 363 (1935).

[34]) P. Gillette, The Cycles that cause the present drought. American Meteorological Society, Tagung in Los Angeles 1935.

[35]) R. Scherhag, Wetterskizze Nr. 1. Annalen der Hydrographie **64**, S. 215 (1936).

The Oxygen-Poor Layer in the Western North Atlantic.

By

H. R. Seiwell.*)

Introduction.

RECENT physical oceanographical investigations have made considerable use of the distribution of oxygen in the sea and have attached particular significance to the minimum oxygen concentration and the oxygen-poor layer (both of which occur at mid-depths).

Since the minimum oxygen concentration and the oxygen-poor layer are quantitatively different, it appears pertinent to define them (this paper deals only with the latter) in order that the adoption of a rigid terminology will avoid confusion. The minimum oxygen concentration occurs at mid-depths and is represented graphically by the principal point of inflexion of the curve characterizing the vertical distribution of oxygen. Theoretically, it is confined to a layer of infinitesimal thickness, but practically, observations from "Atlantis" station 2639 (66°23′W., 35°07′N.) have shown that within a distance of approximately 17 metres both above and below the minimum concentration the existing methods in use by oceanographers are not sufficient to detect any change in oxygen concentration. In general, this minimum concentration has been observed to occur between depths of 200 and 900 metres in the Atlantic and has been traced between latitudes 45°S. to 50°N. Its characteristics in the western North Atlantic and the physical significance of its origin have recently been discussed[1]). On the other hand, the oxygen-poor layer is arbitrarily defined as the layer of water which, containing within its borders the minimum oxygen concentration, embraces that part of the water column where oxygen concentrations are lowest.

*) Contribution No. 139 from the Woods Hole Oceanographic Institution.

[1]) Seiwell, 1937.

Description of Oxygen-Poor Layer.

Over a large part of the western North Atlantic the oxygen-poor layer may be conveniently marked out as that part of the water column within which the oxygen content is 60 per cent. or less of the amount required for saturation at the temperature and salinity of the water if it were at the surface. Thus, in vertical section, the oxygen-poor layer divides the vertical water column into three divisions, or oxygen layers; an upper layer containing the zone of photosynthesis which together with the aid of relatively strong vertical circulation maintains a high oxygen concentration, and the lower oxygen-rich layer where, possibly because of lesser organic oxidation per unit time, the oxygen content is again high.

The range in thickness of the oxygen-poor layer (determined by the position of the isolines of 60 per cent. relative saturation) showed a definite regional variation within the western North Atlantic[2]). In a north-south direction along the 40th meridian ("Atlantis" section B) the thickness of the oxygen-poor layer more or less continuously increased from 0 near latitude 35°N.[3]) to 1100—1200 metres between latitudes 16° and 2°N. Further west, near the longitude of Bermuda, in the north-south direction, the thickness of the oxygen-poor stratum in the convergences off Nova Scotia ranged from 100 to 300 metres, and southward to the latitude of Bermuda it was, in general, 200 to 300 metres thick, while still further south it increased continuously in thickness to more than 500 metres at about latitude 20°N. Still further west, in the American coastwise convergences, the thickness of the oxygen-poor layer decreased rapidly, and, at the latitude of Chesapeake Bay, the layer (so defined) appeared to actually disappear in the convergence, but further westward again expanded to approximately 300 metres thickness.

In mid-Atlantic, north of 40°N., the oxygen-poor layer, as defined by the isolines of 60 per cent., rapidly came to an end (at about 42°—43°N.) due to the presence of oxygen-richer water at mid-depths, and the layer is redefined on the basis of the positions of the 70 per cent. isolines. This oxygen-poor layer was about 500 metres thick at latitude 40°N. and slowly diminished in thickness to about 250 metres at latitude 45°N. and then gave out just north of latitude 49°.

Within the western North Atlantic the regional variation in thickness of the oxygen-poor layer bears certain definite relationships to

[2]) Seiwell, 1934.

[3]) In mid-Atlantic, along the 40th meridian, "Atlantis" stations 2485 to 2488 have shown the existence of a thin layer of water, about 100 metres thick, whose centre rises from about 900 metres to 600 metres between latitudes 39°30′N. and 42°30′N., and whose oxygen content is less than 60 per cent. saturated. A recent study of the minimum oxygen concentration in the western North Atlantic has suggested that the absence of water less than 60 per cent. saturated in the vicinity of latitude 35° ("Atlantis" stations 1157, 1158) is due to the presence of Mediterranean water which has a relatively high oxygen content for the depths in question (Seiwell, 1937).

the regional variation of depth of its upper boundary. In the north-south direction along the 40th meridian with increasing thickness of the layer the depth of the upper boundary decreased from 600 to 800 metres between 35°N. and 25°N. to less than 200 metres between latitudes 16° and 2°N.; a minimum depth of 75 metres characterized the situation of the upper boundary of the oxygen-poor layer at 8°N. From east to west across the central part of the western Atlantic basin (about latitude 35°N.) as far as the American coastwise convergence, the depth of the upper boundary lay generally between 600 and 800 metres, corresponding to a fairly constant thickness (100 — 300 metres) of the oxygen-poor layer, but, within the convergence, as the oxygen-poor layer thinned, the upper boundary rose rapidly surfaceward from depths of 600—700 metres to less than 200 metres; west of the convergence the upper boundary persisted at about 200 metres as the thickness of the oxygen-poor layer increased.

Consumption of Oxygen in the Oxygen-Poor Layer.

A method for calculating oxygen consumption in the oxygen-poor layer of mid-North Atlantic was based on the results of "Atlantis" observations between the equator and 32°N. along the 40th meridian

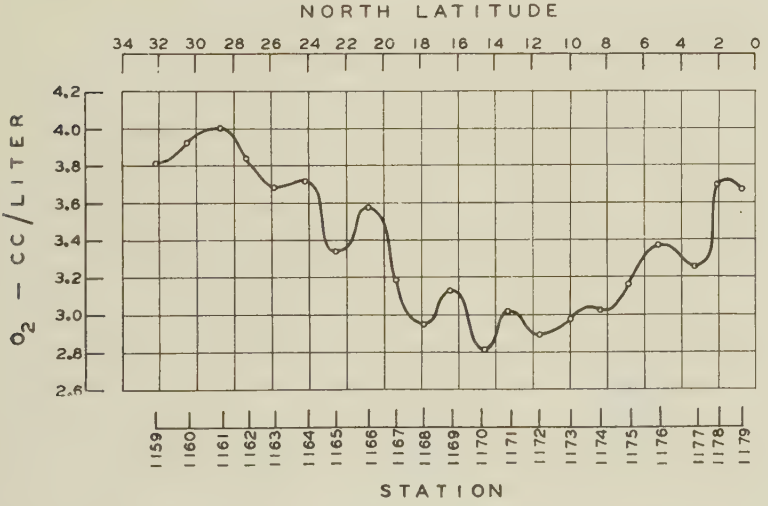


Fig. 1.
Average oxygen content (c.c./litre) of the oxygen-poor layer in mid-Atlantic between 34°N. and equator as determined for "Atlantis" observations. (See text.)

4) This periodicity has been assumed to arise as a result of seasonal variation of phytoplankton growth (in regions where the water masses originate) causing variations in oxygen content of the surface water which continue to persist (under certain conditions) in the water mass after it has been shut off from contact with the surface layer and been removed great distances from the origin regions.

(stations 1159—1179) where its average oxygen content (both absolute and relative values) showed a series of undulating values (maxima and minima) suggesting a periodic variation in the oxygen supply[4]) to this layer (Fig. 1). The trend of the average oxygen content declined both from the north and the south, reaching the lowest average value at about latitude 15°N., suggesting that the water masses making up the oxygen-poor layer in this region were mainly of two origins. And support for this possibility was found in determination of the mean salinity anomaly[5]), which showed that one type of water having an anomaly range of 0·05‰ to —0·08‰ characterized the minimum oxygen layer between latitudes 34°N. and 18°N., while a second type with anomaly ranging from —0·31‰ to —0·39‰ characterized the layer between latitudes 12° and 1°N. Hence it appeared that the principal water mass making up the minimum oxygen layer to the north of 18°N. originated in northern latitudes and was spreading southward, and that south of 12°N. it originated in high southern latitudes and was spreading northward; between 12°N. and 18°N. there was a mixing and counteraction of these two water types.

The final assumptions made in the consumption calculation are: (a) that the distance between successive maxima or successive minima of the mean oxygen content represents the mean annual distance the water of the oxygen-poor layer had moved in a north-south direction[6]), and (b) that the decline in amplitude from one maxima or minima to the next succeeding maxima or minima is due to oxygen consumption as the water was displaced an equal horizontal distance (the effect of lateral and vertical mixing may be disregarded for purposes of calculation). Use of the former assumption gave the mean, approximately north-south, component of this layer to be 1·4 centimetres per second; and use of the latter gave the average annual oxygen consumption between latitudes 32°N. and 15°N. to be 0·34 to 0·63c.c. per litre, and between 11° and 0° to be 0·31 to 0·42c.c. per litre. The mean of all values was 0·42c.c. per litre per year, representing a mean annual reduction of about 13 per cent. of the amount of oxygen present in the oxygen-poor layer.

Because of the assumptions involved these results do not have a high degree of accuracy and may deviate significantly from the true values, but since they are the only ones available on oxygen consumption in the deep ocean basins, they may, within reasonable limits, be accepted until further investigation reveals more satisfactory methods. The validity of the results primarily depends on the ability of the water masses to retain seasonal oxygen changes for great distances from their origin regions, but this question must remain

[4]) See p. 279.

[5]) This calculation of salinity anomaly was made according to the average relation between temperature and salinity of the North Atlantic as found by Helland-Hansen (Helland-Hansen, 1930).

[6]) Each oscillation of the mean oxygen curve for the minimum oxygen layer is fixed by three to five points (representing three to five stations) which are sufficient to determine the form of the curve within reasonable limits.

unanswered at present. Other questions which have arisen concerning the validity of the observed oxygen maxima and minima are based on possibilities of error of the oxygen determination and on the effects of short-period vertical oscillations. However, with regard to the former the reality of the maxima and minima (plotted in Fig. 1) is shown because the average difference of 0·25c.c. per litre between an oxygen maximum and its succeeding minimum is more than eight times the probable error of the oxygen titration (±0·03c.c. per litre).

Since the oxygen-poor layer is not referred to any fixed level (being bounded by isolines of 60 per cent. saturation) the effect of vertical oscillations of the water column on its average oxygen content can enter only in so far as such oscillations produce convergences and divergences of the layer itself (due to vertical variations of amplitude and phase of the oscillations; S e i w e l l, 1937). It is conceivable that a convergence of the minimum oxygen layer might squeeze out the oxygen-poorest water, thus raising the average oxygen content of the entire minimum layer, or a divergence might admit oxygen-poor water, thus lowering the average oxygen content of the entire layer. However, it is highly improbable that a situation due to vertical oscillation of the water mass could occur in such a way as to correspond with the time of sampling and produce the observed regular occurrence of the

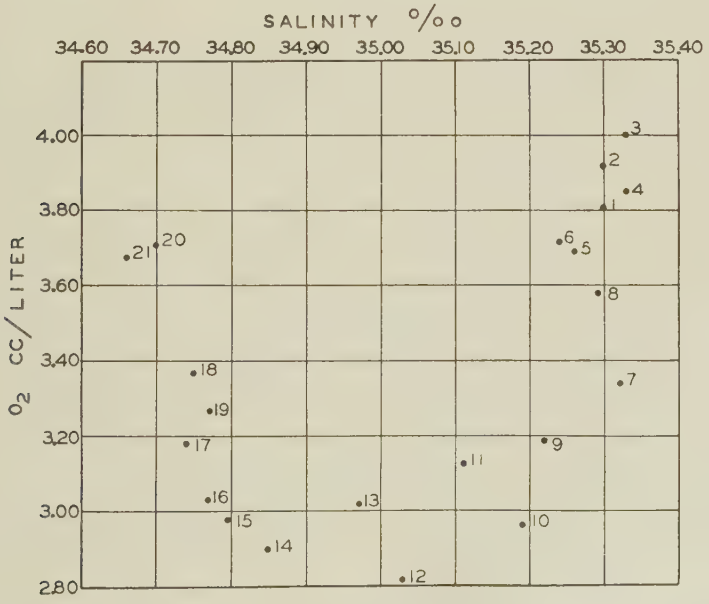


Fig. 2.
Average oxygen (c.c./litre)-salinity (°/oo) correlation in oxygen-poor layer in mid-Atlantic between latitude 34°N. and equator based on "Atlantis" observations. Figures 1 to 21 refer respectively to stations 1159 to 1179.

undulations along the 40th meridian over a distance approximately 2,000 miles northward from the equator (Fig. 1). The agreement of the trend of the average oxygen values with the observed hydrographic conditions is too significant to be disregarded, and, furthermore, no evidence for short period oscillations is shown by the average oxygen-salinity correlation for the minimum oxygen layer (Fig. 2).

The question of seasonally conditioned variations of oxygen and other oceanographic characteristics in subsurface water masses has been recently discussed by Wüst (1935) and he concluded that it is questionable if variations of oceanographic factors in the "Kernschichten" (nuclei) of the subantarctic intermediate water and the upper and middle North Atlantic deep water are conditioned by seasonal variations at their origin regions. In support of this, Wüst uses various examples of what appear to be aperiodic variations of oceanographic characteristics which may be caused by changes in the circulation, by pulsations of the water masses, and also by deviations of stations from the principal axes of outspreading water masses (the latter refers to his conception of the Atlantic circulation). However, for the case under consideration, it appears extremely unlikely that the regular series of oscillations within the minimum oxygen layer could be entirely aperiodically conditioned over a distance of approximately 2,000 miles, and it must be admitted that the evidence is just as deficient to support an aperiodic contention as it is to support the idea of seasonally conditioned oscillations.

Evidence that the southern half of the oxygen-poor layer in mid-North Atlantic (between 35°N. latitude and the equator) occurred chiefly within the remnants of subantarctic water, which penetrated into the southern part of this ocean, and also that the northern half of this layer was influenced by Mediterranean water having a south component is obtained by comparing Iselin's chart of salinity anomalies, for "Atlantis" mid-North Atlantic section of 1932 (stations 1157—1179)[7]), with the chart of the minimum oxygen layer in this same oceanographic section[8]). It is seen that south of 20°N. large negative salinity anomalies characterize the vertical position occupied by the oxygen-poor layer, whereas north of 25° there are high positive salinity anomalies, and between 20°N. and 25°N. the two influences appear to counteract each other. Also, in the southern half of this section the minimum oxygen concentration lay close to the depths of the maximum salinity anomaly and the intermediate salinity minimum, the latter characteristic (which between 0° and 22°N. in this section generally occurs between depths of 700 to 800 metres) marks, according to Wüst's (1935) conception, the nucleus of the subantarctic water entering the North Atlantic[9]).

[7]) Iselin, 1936, page 89, Fig. 55.
[8]) Seiwell, 1934, page 13, Fig. 6.
[9]) Wüst (1935) places the principal axis of outspreading of subantarctic water to the west of the "Atlantis" mid-Atlantic oceanographic section.

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A Simplified Method for the Determination of Calcium in Sea Water.

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IT is a well-known fact that the quantitative precipitation of calcium as oxalate offers certain difficulties in the presence of magnesium. The results are generally too high, owing to some magnesium being precipitated with the calcium. At the same time some of the calcium may remain in solution, in spite of the solubility of calcium oxalate (6mg. per litre in pure water at room temperature) being about fifty times smaller than that of magnesium oxalate (300mg. per litre). The reason for this behaviour is not quite clear, but the fact that magnesium forms a complex with oxalate ions probably, at least in part, accounts for it. A definite theoretical explanation is still lacking and we have in each case to find out empirically what conditions of precipitation will give the best results.

The magnesium content of sea water is in equivalents about five times that of calcium. Therefore the risk of a magnesium contamination of the precipitate is especially great for sea water. For this reason Thompson and Wright (6) recommend triple precipitations, while Kirk and Moberg (2) obtained very good results with only two precipitations. In looking through the literature, before starting an investigation on the calcium content of Baltic water, the present author found, however, that the results obtained by Hahn and Weiler (1) and by Popoff, Waldbauer and McCann (4) seemed to justify an attempt to get accurate results with only one precipitation.

Hahn and Weiler investigated the conditions for complete precipitation of calcium from solutions not containing magnesium or other metals and found that the most accurate values were obtained "at extreme dilution." They got equally good results when precipitating in ammoniacal solution or in such containing acetic acid and acetate. Popoff, Waldbauer and McCann examined solutions also

containing magnesium and found complete recovery of the calcium only when so much alkali oxalate had been added that it sufficed both for the calcium *and* the magnesium present. As magnesium forms a complex with oxalate ions, part of the oxalate added will be fixed in the complex ions, and an excess must be used in order to ensure complete precipitation of the calcium. The phenomenon is of course complex in more than one way: the magnesium oxalate ions probably contain more than one oxalate ion to one magnesium ion, but on the other hand they are to a certain extent dissociated. Popoff, Waldbauer and McCann found that an oxalate amount equivalent to the sum of the calcium and magnesium present was enough for complete precipitation of the calcium. Both Hahn and Weiler and Popoff, Waldbauer and McCann emphasize the well-known fact that slow precipitation is a *sine qua non* for success.

These results were now applied to the sea-water determination. As the magnesium content of the oxalate precipitate is considered to increase with increasing pH in the final solution it was decided not to make the solution alkaline at all, but to apply the results of Hahn and Weiler and to precipitate in acid solution with sodium acetate. The final pH value will then lie between 4 and 5, which is in accordance with the results of Shohl (5) who investigated the influence of varying pH on the calcium precipitation and found correct values between pH 4 and 7·4. The first attempts gave promising results, and the concentrations accidentally chosen to begin with later proved to be the best ones. The different phases of the investigation will not be recorded here: it may only be stated that it was found, step by step, that the procedure of precipitation could be much simplified, compared to earlier methods, and the time of a complete analysis shortened — without considerable loss of accuracy. The principle of the method finally adopted is to precipitate at so great a dilution that the oxalate does not form at once, the liquid remaining quite clear for half a minute or so. Then it is not necessary to add the reagent drop by drop, nor to stir vigorously. Much time is thereby saved, yet the precipitate forms slowly and the crystals of calcium oxalate become very coarse. It was also established that these conditions gave the surest and most even results. The details of the method will be described below.

The following reagents are needed:—

1) Ammonium oxalate solution, 2·5%,
2) Hydrochloric acid, 2N,
3) Sodium acetate, 2N. This should be of a good quality, not reducing permanganate. Merck's preparation labelled "Indifferent gegen Kaliumpermanganate, nach Reinitzer" was used.
4) Potassium permanganate, about 0·05N, preferably somewhat stronger, prepared with the usual precautions described in textbooks and standardized against pure 0·05N sodium oxalate.

5) Sulphuric acid, conc. acid diluted with an equal amount of water.
6) Washing solution, saturated with calcium oxalate, prepared by dissolving 30c.c. glacial acetic acid and 68g. sodium acetate in 2 litres of dist. water; it is heated some time with precipitated and washed calcium oxalate and allowed to stand for a couple of days; it should be filtered before use and contain about 15mg. Ca per litre.
7) Manganous sulphate, 2N, a few c.c.

As much sea water as contains from 4 to 5mg. of calcium is diluted to 75c.c.; sea water of 19·5‰ Cl is thus diluted about six times. Five c.c. of 2N hydrochloric acid and 5c.c. of 2·5% ammonium oxalate are added. This amount is enough for precipitating 5mg. Ca in the presence of six times its equivalent of magnesium. The solution is then heated on a water bath or hot plate until steaming. No stirring rod is used. The contents are mixed by gently shaking the beaker, which therefore should not be too small; 250c.c. beakers are suitable. Now precipitation is effected by adding *in one portion* 5 to 6c.c. of 2N sodium acetate. The beaker is again gently shaken and left on the water bath for 1½ hours. Within half a minute the liquid becomes turbid and within fifteen minutes a coarsely crystalline precipitate has settled out at the bottom of the beaker, the solution being quite clear again[1]). After 1½ hours, precipitation is complete and the volume of the sample has been reduced to about one-third; the beakers are now taken from the bath and allowed to cool during one hour, but should not be left standing overnight or else the results will be too high. For the further treatment, two methods may be followed.

Hahn and Weiler recommend indirect determination of the calcium by titration of the excess of oxalate added. In the beginning of the work on the Baltic material this method was followed. Then 30c.c. of 0·06N sodium oxalate was used instead of ammonium oxalate and accordingly less water added. The solutions with the calcium oxalate precipitate were made up to 100c.c., filtered through a dry filter (the first portion rejected!) and 50c.c. titrated with 0·05N potassium permanganate. The results were good (see below), but on account of two theoretical objections that can be raised against such a procedure it was soon abandoned. Firstly only half of the oxalate is titrated so that the titration error becomes doubled and secondly sea water itself to some extent reduces permanganate (chlorine, organic matter!), which circumstance renders it somewhat difficult to observe the proper end-point of the titration. As this method, moreover, does not represent any saving of time, the more common procedure to filter the precipitate under suction, wash, dissolve it in sulphuric acid and titrate with permanganate is more to be recommended.

[1]) During the digestion on the water bath the beaker or rather the beakers — ten analyses generally being made at the same time — were shaken now and again. This point was not checked and it may have been unnecessary.

Hahn and Weiler experienced some difficulties on this point, probably due to their using pure water as washing solution. Though the solubility of calcium oxalate is low, it seems to adjust itself very easily to environment. The present author, in one instance, found too low values when using a new washing solution; its calcium content was controlled and found to be only 10mg. per litre. It was now treated again with calcium oxalate and the Ca content rose to 15mg. After this correct values were again obtained. It is probable that pure water, saturated with calcium oxalate, could be used for washing. The solution prescribed above was chosen in order that its pH should be about the same as that at which the calcium oxalate had been precipitated.

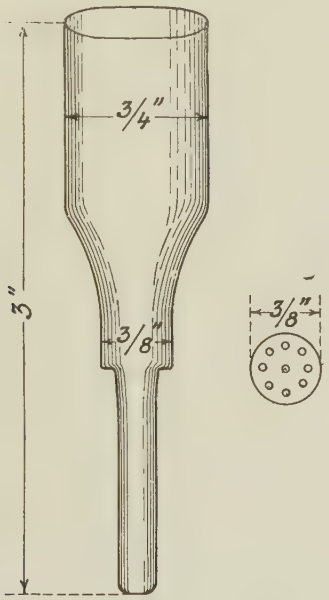

Fig. 1. Microfilters for calcium oxalate precipitate.

For the filtration, small glass funnels (Fig. 1) with platinum disk and asbestos pad, as described by Kirk and Schmidt (3) and Kirk and Moberg were used. Kirk and Schmidt give the following description of the filters:— "On the square shoulder is placed a platinum plate cut from foil with a cork borer, and having small punched holes. It is from a quarter to three eighths of an inch in diameter. In constructing the filter it is desirable that the glass should not be constricted below the shoulder. The glass blowing consists simply in attaching a tube of about ¾ inch cross section to one of about ⅜ inch cross section, which in turn is attached to one of about 4mm. cross section. This is slightly pushed together while hot, thus forming the shoulder."

The asbestos, "preferably short fiber, Italian, washed and ignited", should be treated before use with permanganate as described by K i r k and M o b e r g:— "Before use this is rubbed in a mortar to shorten the fibers further (after which it is heated with dilute sulphuric acid. Potassium permanganate is added to a faint permanent pink, followed by more heating. When it no longer discolors permanganate it is thoroughly washed with water and finally suspended in a flask of water. Such asbestos gives no blank titration with permanganate .... A filter is prepared by first placing the platinum disk in the shoulder of the glass portion, making sure it is squarely seated. Asbestos, treated as described above, is next run in preferably from a pipet with an enlarged orifice. Enough is used to form a layer about 1mm. thick. This is washed under vacuum two or three times."

The present author freed the suspension of asbestos from very small particles by decantation. Then no difficulties from slow filtration were ever experienced.

Since after the filtration and washing the precipitate is transferred into the same beaker as before, it is not necessary completely to wash out the precipitate from the beaker; the latter should just be carefully rinsed with the washing solution. The wash bottle and bottle for distilled water were operated with rubber bellows and their outlet tubes were extended with rubber tubing and provided with pinchcocks. In this way washing becomes very efficient and is at the same time more convenient than with an ordinary wash bottle. The beaker is rinsed three to four times and the filter a few more times. Since the washing solution contains a small amount of calcium, it should be removed from the beaker as completely as possible, yet no error from this source need be feared, as 1c.c. of the solution will only contain about 0·015mg. of calcium and the amount remaining in the beaker will be much smaller.

After washing, the filter pad and disk are pushed out of the filter into the beaker with a small stirring rod, inserted through the bottom of the filter. The filter is carefully rinsed with cold water; the calcium oxalate crystals being very coarse it is not necessary to use hot sulphuric acid as generally prescribed. The sulphuric acid is added afterwards — 3 to 5c.c. is sufficient. The solution is now brought to near the boiling point on a hot plate, taken away and titrated drop by drop with 0·05N permanganate. For convenience one or two drops of manganosulphate may be added just before starting the titration. This is not necessary, but hastens the reaction between oxalate and permanganate, otherwise slow in the beginning. For the titration a 5c.c. burette should be used, calibrated in 0·01c.c. and provided with a filling device so arranged that the permanganate does not come into contact with any rubber.

The method was tested on a solution containing sodium chloride, magnesium sulphate, and calcium chloride in about the same proportions as in sea water. The calcium was added as carbonate and dissolved in a few c.c. of hydrochloric acid. Merck's precipitated calcium

carbonate "Pro Analysi" was used; it was tested for moisture and its content of CaO controlled. The salinity of the solution corresponded to 7‰. Portions of 50c.c., theoretically containing 5·00mg. of calcium, were analysed. The following Table 1 shows two series of six analyses each.

Table 1.

Analysis of artificial Sea Water.

Ca-Content 5mg. per 50c.c.

	1.	Deviation from theoretical Value	2.	Deviation from theoretical Value
Values found:	5·03mg.	+0·03mg.	5·02mg.	+0·02mg.
	5·02	+0·02	5·03	+0·03
	5·00	Mean 0·00	4·98	Mean —0·02
	5·00	5·01mg. 0·00	4·99	5·00mg.—0·01
	5·02	+0·02	4·99	—0·01
	5·02	+0·02	5·00	0·00

Standard deviation ±0·02mg.

The treatment of the first series differed from the description given above in that another portion of 5c.c. of sodium acetate was added when the samples had stood for 1½ hours on the water bath, after which they were left on the bath for a quarter of an hour more. This was according to an earlier feature of the method when, following a suggestion by Popoff, Waldbauer and McCann, precipitation was done in two stages. Series 2, made according to the description above, proves, however, that this is unnecessary and a single precipitation rather to be preferred.

The method was further tested on a series of 48 samples of Baltic water. All analyses were made at least in duplicate, but a great many samples were analysed three or four times. As a series of ten analyses can easily be completed within six hours this did not represent very much additional work, but a better picture of the reliability of the method was thereby gained. In the preliminary work it was often noticed that duplicate analyses belonging to the same series checked exceedingly well, whereas greater deviations appeared between analyses belonging to different series. Evidently small unintentional differences in the treatment may cause small systematic errors, which influence all analyses of one and the same series in the same way. For this reason a sample was never analysed twice in the same series, but each series comprised five samples that had already been analysed, and five new ones. If the first five checked well with the earlier analyses, there was reason to believe that the five new ones were correct also.

Table 2 contains the calcium amounts found in 14 samples which were analysed more than twice. The chlorinity of the sample and the amount of water used for one analysis are given in Columns 1 and 2, Column 3 contains the calcium amounts found therein, and Column 4 the means of the observed values.

Table 2.

Analyses of 14 Samples of Baltic Water.
Direct Titration of Oxalate in Precipitate.

1. Cl ‰	2. Quantity of Water c.c.	3. Calcium found mg.				4. Mean mg.
1·70	80	3·97	·90	·92		3·93
1·71	80	3·67	·62	·68		3·66
1·80	80	3·91	·83	·85		3·86
2·70	65	4·70	·64	·67		4·67
2·74	65	4·83	·78	·81		4·81
2·96	60	4·75	·70	·69		4·71
3·54	50	4·63	·64	·68	·74	4·67
5·28	30	3·91	·91	·94		3·92
5·47	30	4·01	·06	·02		4·03
5·53	30	4·07	·15	·09		4·10
5·81	30	4·23	·19	·28	·23	4·23
6·08	30	4·45	·42	·48		4·45
6·35	30	4·59	·56	·62		4·59
6·60	30	4·72	·68	·79	·75	4·74

Average deviation	from	the mean:	0·025mg.
Standard	,,	,, ,, ,, :	±0·030mg.
Maximum	,,	,, ,, ,, :	0·07 mg.
Minimum	,,	,, ,, ,, :	0

The material in Table 2 was analysed by direct titration of the oxalate amount in the precipitate. Table 3 records analyses of seven samples, the calcium contents of which were found from the difference between oxalate added and excess oxalate determined by titration.

Table 3.

Analyses of 7 Samples of Baltic Water.
Titration of Excess Oxalate.

1. Cl ‰	2. Quantity of Water c.c.	3. Calcium found mg.				4. Mean mg.
3·34	50	4·39	·40	·35	·43	4·39
3·36	,,	4·41	·38	·33	·38	4·38
3·43	,,	4·46	·51	·43	·50	4·48
3·45	,,	4·53	·48	·41	·50	4·48
3·45	,,	4·53	·51	·48	·57	4·52
3·48	,,	4·56	·51	·52	·54	4·53
4·03	,,	5·11	·13	·12	·18	5·14

Average deviation	from	the mean:	0·025mg.
Standard	,,	,, ,, ,, :	±0·031mg.
Maximum	,,	,, ,, ,, :	0·07 mg.
Minimum	,,	,, ,, ,, :	0

In both cases the standard deviation ("root-mean-square deviation from the mean") is ± 0·03mg. This number thus gives us the absolute accuracy of the method and tells us that in about two-thirds of the

cases we have to expect a deviation from the mean that is equal to or smaller than 0·03mg. As in each case about 4·5mg. were determined, the relative accuracy of a single determination will be about ± 0·7%; the error in the mean values will of course be considerably smaller.

Table 4 contains analyses of three samples, the calcium contents of which were determined both by direct and by indirect titration of the oxalate. The material is very small, it is true, yet it indicates the possibility of a small systematic difference between the two methods, all values found by indirect titration being lower than the others, although the differences lie entirely within the range of admissible analytical errors. As pointed out above this method was abandoned because of theoretical objections against it.

Table 4.

Analyses of 3 Samples of Baltic Water.
Indirect and direct Titration of Oxalate.

1. Cl ‰	2. Quantity of Water c.c.	3. Calcium found by Indirect titration mg.		Direct titration mg.		
3·38	50	4·40		4·42		
3·41	„	4·49	·48	4·50		
3·71	„	4·81	·82	4·88	·88	·94

Finally it may be noted that the quantities of reagents and the time of digestion are adjusted for the determination of 5mg. of calcium or less. If greater amounts are to be determined the method must be modified. One cannot expect accurate values for 10mg. calcium, for instance, simply by doubling all measures; a special study of the proper time of digestion must be made. In the present case the amount of 5mg. was chosen because it enabled the combination of a satisfactory accuracy with the possibility of completing a set of analyses within a convenient length of time.

Zusammenfassung.

Eine einfache Methode zur Bestimmung kleiner Mengen Calcium als Oxalat wird beschrieben. Sie beruht auf dem Prinzip, dass die Fällung bei so grosser Verdünnung vorzunehmen ist, dass der Niederschlag nicht sogleich entsteht, die Flüssigkeit vielmehr noch eine Zeit lang nach dem Hinzufügen des Reagenzes klar bleibt. Das Reagenz kann dann auf einmal zugefügt werden, und es ist auch nicht notwendig, sehr lange und kräftig umzurühren, wie das gewöhnlich vorgeschrieben wird. Hierdurch wird u.a. viel Zeit gewonnen und mehrere Proben können innerhalb kurzer Zeit behandelt werden. Der Niederschlag bildet sich jedoch langsam und wird grob kristallinisch. Unter diesen Bedingungen ist einmalige Ausfällung genügend, um das Calcium im Meerwasser genau zu bestimmen, trotz Anwesenheit einer vielfachen Menge von Magnesium.

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The Calcium Content of Baltic Water.

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IN a recent publication von Brandt (1) gives a survey of all determinations of the calcium content of Baltic water hitherto published. He records in all 39 analyses made during the last century, which give us an idea of the order of magnitude of the calcium concentration; they cannot, however, serve for comparative purposes as in many cases chlorine determinations on the same water samples are lacking. Neither have we any clue for judging the accuracy of these analyses, the latest of which date from 1884. Fifty years later, in 1935, Zarins and Ozolins (8) published an extensive investigation of the water in the Bay of Riga and in the Baltic off the Latvian coast, their most westerly station nearly coinciding with the Finnish station F81 (Lat. 57°22′N., Long. 19°57′E.) above the central depression of the Baltic. Their material comprised about 70 calcium analyses on water from all depths. Finally von Brandt in the above-mentioned paper publishes nearly 300 analyses of surface water collected in 1935 and 1936 during several voyages from Pillau to Helsingfors and back, and along the German coast as far as Kiel and back.

The present material comprises analyses of only 48 samples of surface and bottom water collected during the summer cruise, in July 1935, of the s.s. "Nautilus" from the Gulf of Finland, the Gulf of Bothnia, and the northern half of the Baltic proper. In spite of the smaller number of samples this material is more comprehensive than the two preceding investigations in so far as it covers a greater area of the sea. It was originally meant as a survey of the calcium content in these parts of the Baltic, but the surprisingly simple relationships between calcium content and chlorinity which it revealed, give the results far more scope than was expected.

The Material.

Table 1 gives all the data of the investigation. The analyses were carried out on filtered samples according to the method described in the previous paper. The standard error of a single determination was

Table 1.

Calcium Content of Baltic Water.

1. Station and Depth; m.	2. Lat. N.	3. Long. E.	4. Distance from Bottom m.	5. Cl ‰	6. Ca mg./kg. observed	7. Ca mg./kg. calculated	8. Diff.
Gulf of Bothnia:							
F 1, 0	65°38′	23°47′		0·94	26·4	26·1	+0·3
F 8, 80	64°40·5′	22°44′	10	2·03	54·1	54·2	—0·1
F13, 0	63°47·5′	21°29′		1·80	48·3	48·3	0
F16, 0	63°30·5′	20°54′		1·71	45·7	46·0	—0·3
F19, 0	63°09′	19°27′		2·43	64·0	64·5	—0·5
F19, 150			21	3·19	83·7	84·1	—0·4
F24, 0	62°50·5′	18°56′		2·26	60·0	60·2	—0·2
F24, 175			27	3·17	84·1	83·6	+0·5
F26, 0	61°59′	20°04′		2·96	78·4	78·2	+0·2
F28, 40	61°07·5′	20°55′	3	3·01	80·1	79·5	+0·6
F29, 100	61°03′	20°16′	7	3·41	89·6	89·8	—0·2
F30, 100	61°04·5′	19°35′	15	3·30	86·7	87·0	—0·3
F31, 0	61°11′	18°37′		2·89	76·2	76·4	—0·2
F31, 59			1	2·97	78·5	78·5	0
F32, 0	61°12′	17°52′		2·71	72·4	71·8	+0·6
F32, 60			10	2·91	77·1	76·9	+0·2
F33, 0	60°33·5′	18°55′		2·68	70·9	71.0	—0·1
F33, 109			1	3·54	93·2	93·2	0
F64, 0	60°11·5′	19°09′		2·70	71·7	71·5	+0·2
Gulf of Finland:							
F37, 0	60°35′	28°28′		1·51	43·8	44·2	—0·4
F40, 0	60°06·5′	28°48′		1·24	37·5	37·8	—0·3
F40, 30			8	2·93	78·2	78·1	+0·1
F41, 0	60°07′	28°04′		1·70	49·1	48·7	+0·4
F41, 40			12	3·36	87·2	87·6	—0·4
F43, 0	60°20′	26°58′		2·35	64·4	64·2	+0·2
F46, 0	59°47′	27°05′		2·54	69·0	68·7	+0·3
F46, 60			7	4·03	102·3	102·3	0
F47, 0	59°37·5′	26°58′		2·46	67·1	66·8	+0·3
F47, 40			10	3·45	89·3	89·6	—0·3
F50, 0	59°50′	25°37′		2·74	73·7	73·5	+0·2
F56, 0	59°36·5′	24°21′		3·21	85·4	84·7	+0·7
F58, 0	59°47′	22°59′		3·16	83·7	83·5	+0·2
F58, 34			1	3·45	90·2	89·6	+0·6
F61, 0	59°26′	23°09′		3·19	85·0	84·2	+0·8
F61, 90			7	5·47	133·5	134·0	—0·5

about $\pm 0{\cdot}7\%$; all analyses were, however, made at least in duplicate, several samples being analysed three or four times. The table gives the means of all analyses which were considered good from a methodical point of view, with the exception of one, which was rejected on account of the considerable deviation from two other concordant values.

Table 1. (Continued).

Calcium Content of Baltic Water.

1. Station and Depth; m.	2. Lat. N.	3. Long. E.	4. Distance from Bottom m.	5. Cl ‰.	6. Ca mg./kg. observed	7. Ca mg./kg. calculated	8. Diff.
Baltic:							
F69, 0	59°46′	19°47′		3·19	85·0	84·2	+0·8
F71, 0	59°30·5′	20°24′		3·27	86·0	86·1	—0·1
F71, 150			8	5·28	129·9	130·1	—0·2
F72, 0	59°14·5′	22°11′		3·34	87·6	87·8	—0·2
F72, 100			7	5·53	136·0	135·2	+0·8
F75, 0	58°54′	20°07′		3·43	89·2	89·9	—0·7
F75, 165			17	6·08	147·3	146·4	+0·9
F78, 0	58°42′	18°26′		3·38	87·9	88·7	—0·8
F78, 375			27	5·81	140·2	140·9	—0·7
F80, 0	58°00′	19°54′		3·48	90·4	91·1	—0·7
F80, 150			38	6·35	151·9	151·9	0
F81, 0	57°22′	19°57′		3·71	97·0	96·6	+0·4
F81, 200			3	6·60	156·7	157·0	—0·3

Average deviation: 0·4mg./kg. or 0·45%,
Standard „ : ±0·4 „ „ .

The calcium content was determined in milligrammes per litre and reduced by calculation to milligrammes per kilogramme. The chlorinities were determined in duplicate according to the usual method. When the investigation was undertaken the samples had been stored for a year and a half, but the fact that the chlorinities in most cases agreed with those determined in 1935 on samples from the same localities and depths (though possibly not from the same water-sampler) showed that no appreciable evaporation had taken place. One-litre bottles of resistant glass ("Neutral-Glas", Bock, Ilmenau) with cork stoppers, soaked in paraffin, had been used; after a year and a half the glass was still absolutely unaffected by the sea water.

The localities from which the water samples had been collected are shown in Fig. 1. There were 27 surface samples and 21 samples of bottom water; in the Gulf of Finland the latter were taken from 1 to 12 metres, in the Baltic from 3 to 38 metres, and in the Gulf of Bothnia from 1 to 27 metres over the bottom. As there were no samples from intermediate depths, the material could be dealt with as "surface water" and "bottom water", which probably helped to bring out more clearly the relationships between calcium content and chlorinity in the separate water masses.

When the calcium contents were plotted as ordinates against the chlorinities as abscissae, it was found that the points formed a slightly curved line, which in its bottom part had two branches. When, however, the values for surface and bottom water and for the different parts of the Baltic were plotted separately, they were found to form straight lines which partly coincided. Four different lines corresponding to:—

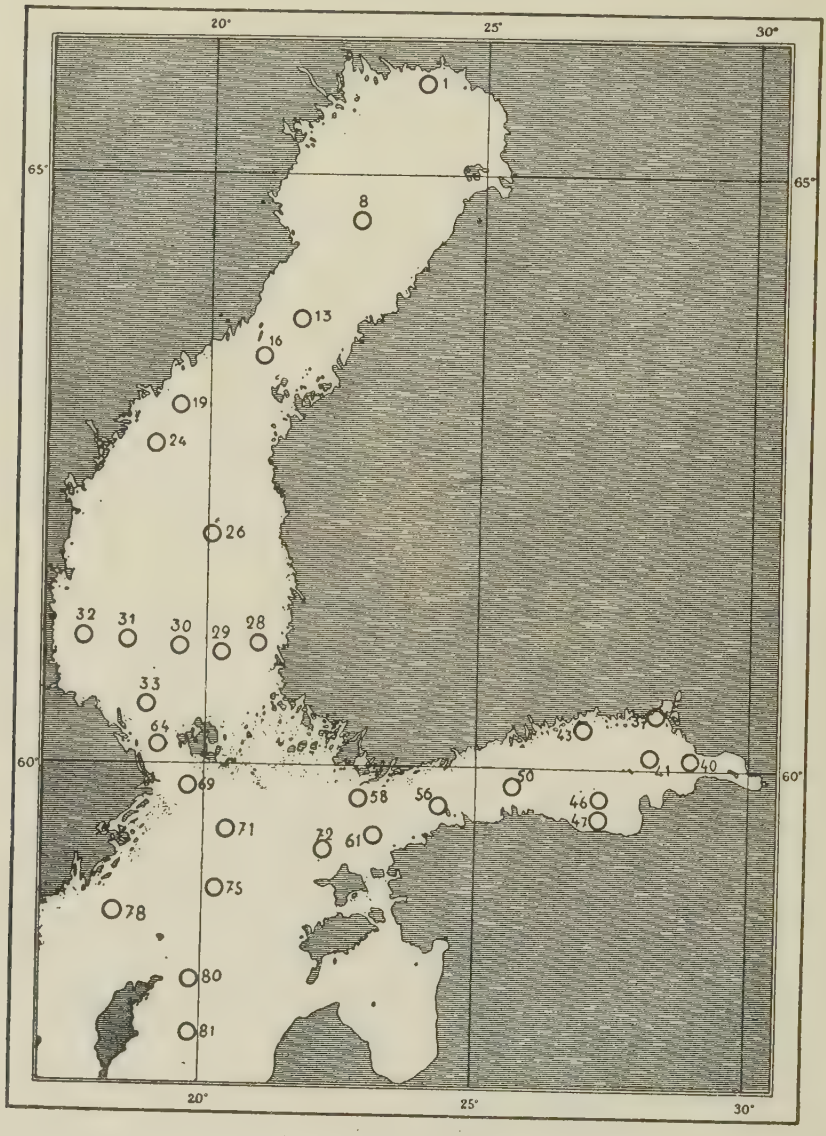

Fig. 1. Chart of Stations.

1) bottom water in the Baltic,
2) bottom water in the Gulf of Finland,
3) surface water in the Baltic and in the Gulf of Finland,
4) surface and bottom water in the Gulf of Bothnia

could be distinguished. These are shown in Fig. 2. For the sake of clearness lines 3 and 4 are drawn separately, the origin of the corresponding ordinates being displaced by 20 and 40 units respectively.

The equations of the four lines were computed from the observed calcium contents by the method of least squares, each single analytical value being used in the calculations and not the means which are given in Table 1. As the material was to a certain extent uneven, the absolute error of the determination varying with the amount of water that had been used for one analysis, the values were entered in the calculations with different weights. Thus calcium amounts determined on 100c.c. of water were given the weight 10, those on 80c.c. the weight 8, and so forth.

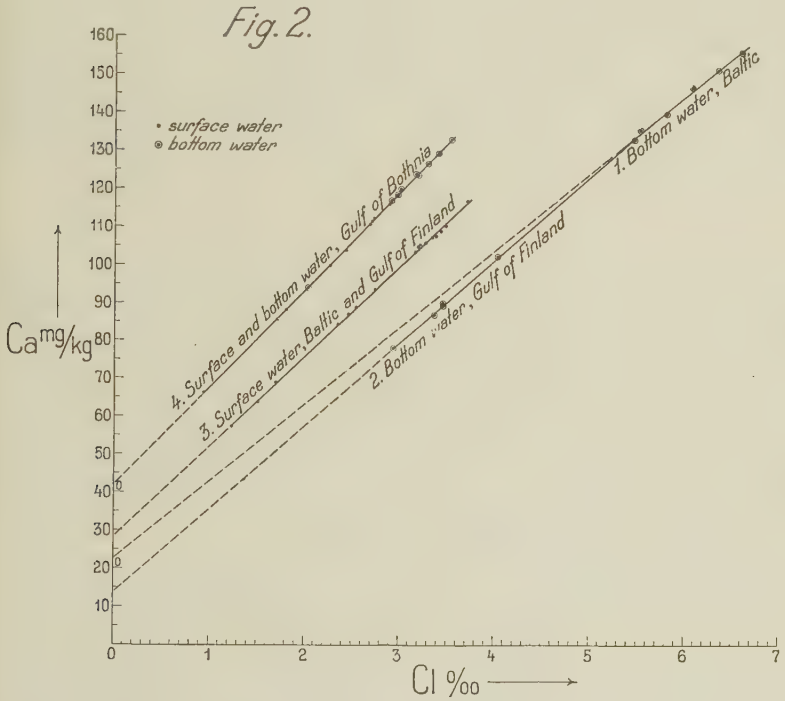

Fig. 2. Calcium content of Baltic water. For lines 3 and 4 the origin is displaced by 20 and 40 units respectively.

In this way the following four equations were arrived at:—

1. Bottom water in the Baltic:
   Ca g./kg. $= 0{\cdot}02260 + 0{\cdot}02036$ Cl‰; $\sigma = \pm 0{\cdot}0006$g./kg.
2. Bottom water in the Gulf of Finland:
   Ca g./kg. $= 0{\cdot}01363 + 0{\cdot}02201$ Cl‰; $\sigma = \pm 0{\cdot}0004$g./kg.
3. Surface water in the Baltic and in the Gulf of Finland:
   Ca g./kg. $= 0{\cdot}00826 + 0{\cdot}02381$ Cl‰; $\sigma = \pm 0{\cdot}0005$g./kg.
4. Surface and bottom water in the Gulf of Bothnia:
   Ca g./kg. $= 0{\cdot}00189 + 0{\cdot}02578$ Cl‰; $\sigma = \pm 0{\cdot}0003$g./kg.

Column 7 of Table 1 gives the calcium contents calculated by means of the above equations, and Column 8 the differences between observed and calculated values. It is seen that the greatest deviation occurring is 0·9mg. per kilogramme, the average deviation being 0·4mg. or about 0·45‰. The standard deviation σ calculated for the whole material is likewise ±0·4mg., but as seen above it varies somewhat in the different water masses. This may be due partly to the above-mentioned unevenness of the material, the absolute error of the determination increasing with the calcium content, and partly to actual deviations from the calculated relationships. The fact that the sum of the analytical error and the local deviation from the calculated value on an average amounts to less than 0·5‰ shows that the distribution of calcium in the Baltic follows quite definite laws. It affords another means for the study of the mixing of water masses. It would be a useful task to study in detail the distribution of calcium in the southern and western part of the Baltic, where the actual mixing with Atlantic water takes place.

Discussion.

If two water masses of different calcium contents and chlorinities are mixed in various proportions and the calcium contents of the mixtures are plotted as ordinates against the chlorinities as abscissae, the points thus obtained will of course form a straight line between the two original calcium contents. The calcium of Baltic water derives its origin partly from Atlantic water entering through the Danish Sound and the Belts, and partly from fresh water brought down to the sea by rivers. These are, however, not mixed directly, the Atlantic water entering principally as a bottom current, which gradually becomes mixed with water of lower salinity.

The relation between calcium content and chlorinity in oceanic water follows the equation:

$$\text{Ca g./kg.} = 0{\cdot}02156\ \text{Cl}‰.$$

It thus forms a line through the origin which is almost parallel to that of Equation 1, the inclination towards the x-axis being 0·02156 against 0·02036 for line 1. The latter is very slightly inclined towards the line for Atlantic water, which means that they have a point of intersection at a high chlorine value. This is quite in agreement with theory: as the one ingredient of Baltic water is Atlantic water, the two lines should have a point of intersection at a chlorine value such as occurs in the North Sea. Simple calculation shows, in fact, that the two lines intersect at Cl = 18·8‰ or salinity 34‰. For Cl = 0 Equation 1 gives us Ca = 0·0226g./kg. Baltic bottom water may thus be regarded as Atlantic water diluted with fresh water containing about 23 milligrammes of calcium per kilogramme. This corresponds to a moderate hardness of about 4 degrees (English). It is remarkable that the content of Atlantic water can be traced in the bottom water as far north as in the central depression.

Neither of the three lines, 2, 3, or 4, cuts the line for Atlantic water (Fig. 3). They all lie entirely above the latter, the chlorine coefficient in all three cases being higher than 0·02156. This, too, agrees with theory, as the water masses which these lines represent are not formed by direct dilution of Atlantic water.

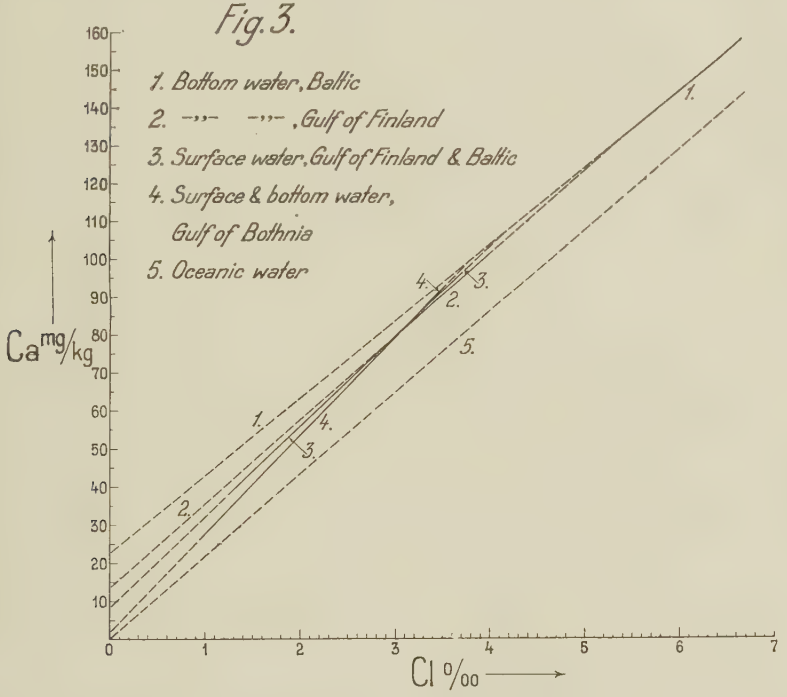

Fig. 3. Calculated calcium content as a function of chlorinity for different parts of the Baltic. Observed calcium values lie within the continuous part of the lines.

Baltic water enters the Gulf of Finland principally as a bottom current in the deep channel (80—100 metres) along the southern side of the gulf. Therefore the line for bottom water in the Gulf of Finland should cut the line for bottom water in the Baltic at such a chlorinity value as occurs in the mouth of the gulf. This is in fact the case, the point of intersection lying at Cl = 5·44‰, or at about the same chlorinity as that found at station F61, viz. 5·47‰. The calcium content at this station, in a sample collected seven metres from the bottom, was found to be 133·5mg./kg., while according to Equation 1 it should be 134·0mg., and according to Equation 2, 133·7mg. — again a good agreement. In the calculations it was counted among Baltic samples.

A common equation was computed for surface water in the Baltic and in the Gulf of Finland. It is possible that if more material had been available it would have been found necessary to separate the two areas.

The differences between observed and calculated values are not higher here than elsewhere, but they are possibly systematical. For all stations in the Gulf of Finland, except for the two innermost, the deviations are positive, while they are negative for all Baltic stations except for the most northerly, F69, and the most southerly, F81. As the highest deviation was only 0·8mg./kg., it was all the same not found advisable to try and draw any further conclusions from these facts. The calculated relationship holds good, with a standard deviation of ±0·5mg./kg., for all surface samples from F40 to F78, and from F69 to F81 (see Fig. 1).

As first shown by Witting (7), the water in the Gulf of Bothnia is more homogeneous than in the Baltic or its continuation, the Gulf of Finland. The channels in the archipelago and the bank which separates the Åland Sea from the Baltic proper are nowhere deeper than 50 metres. Therefore Baltic bottom water can never penetrate into this gulf and the salinity of the water is dependent upon the surface layer only. A consequence of this is that the difference in salinity between surface and bottom water is much less pronounced here, even at the deepest stations, than elsewhere in the Baltic.

These conditions are reflected in the calcium contents. Not only is the relation between calcium content and chlorinity the same for surface and bottom water, but the deviations of observed from calculated values are, moreover, lower here than anywhere else in the area investigated. The highest deviation is 0·6mg./kg. and the standard deviation only ±0·3mg.; positive and negative deviations occur evenly. The point of intersection with the line for Baltic surface water lies at $Cl = 3{\cdot}23‰$ or $S = 5{\cdot}86‰$, a value lying within the range of surface salinities in the northern part of the Baltic proper.

It is of interest, too, to compare with each other the constant terms of the four equations. These can be considered as average values for the calcium content of the fresh water with which the sea water has been mixed, even though direct mixing has not taken place. The lowest value, 2mg./kg., we find for the Gulf of Bothnia, and the highest, 23mg., for Baltic bottom water, while bottom water in the Gulf of Finland and surface water here and in the Baltic present intermediate values. It is a well-known fact that most of the affluents to the Gulf of Bothnia, which have their source in and flow through the vast areas of primitive rocks in Finland and in northern Sweden, are very poor in lime. The affluents to the southern part of the Baltic, on the other hand, are richer in lime. In the Gulf of Finland the lime content of the affluents is higher on the Estonian side, where the bottom water chiefly becomes diluted, than on the Finnish side where, on an average, the outflow to the Baltic takes place. In accordance herewith the constant term is higher for the bottom water of the Gulf than for the surface water.

In an earlier publication (4) I expressed the opinion that the calcium content of the Baltic, when better known, would not be found directly proportional to the chlorinity, as in oceanic water. This view

has been fully confirmed by the present investigation. Another supposition, put forth at the same time, has, however, not found support. On account of the fact that Baltic water is undersaturated with respect to calcium carbonate and the calcium content at the same time relatively higher than in oceanic water, it was supposed that this, at least in part, was due to dissolution from whatever supplies of carbonates the water is in contact with. In the southern part of the Gulf of Bothnia, for instance, the bottom deposits are rich in lime (up to 40%). If dissolution takes place and these supplies contribute to the calcium content of the water we ought to find here, in the vicinity of the bottom, higher values than further north where the deposits are entirely free of lime. As we have seen, this is not the case. The bottom waters in the southern part of the gulf fit quite as well into the general relationship as those further north. If dissolution takes place it is so

Table 2.

Comparison with the Work of Zarins and Ozolins.

1. Station and Date	2. Depth	3. Cl ‰	4. Ca mg./kg. observed	5. Ca mg./kg. calculated	6. Diff.
Surface water:					
5	0	3·562	94·1	93·1	+1·0
18·10·1933	20	3·564	94·3	93·1	+1·2
	40	3·701	97·9	96·4	+1·5
5	0	3·732	98·8	97·1	+1·7
8·6·1934					
5	0	3·631	96·2	94·7	+1·5
18·10·1934					
6	0	3·655	97·1	95·3	+1·8
17·10·1933	10	3·670	97·6	95·6	+2·0
	20	3·716	98·2	96·7	+1·5
	30	3·716	98·2	96·7	+1·5
6	0	3·612	95·7	94·3	+1·4
7·6·1934	30	3·797	100·3	98·7	+1·6
6	0	3·733	98·9	97·1	+1·8
2·11·1934	30	3·733	99·2	97·1	+2·1
6a	0	3·646	96·6	95·1	+1·5
8·6·1934	40	3·835	101·2	99·6	+1·6
6a	0	3·709	98·3	96·6	+1·7
2·11·1934					
Bottom water:					
5	160	5·986	146·0	144·5	+1·5
18·10·1933	180	6·163	149·3	148·1	+1·2
	200	6·218	150·6	149·2	+1·4
	220	6·218	150·6	149·2	+1·4
5	220	6·518	157·8	155·3	+2·5
8·6·1934					
5	200	6·181	150·1	148·5	+1·6
18·10·1934					

Average difference: +1·6mg.

slight that the analyses do not reveal it. The higher calcium content in relation to chlorinity, which the analyses do reveal — about 15mg./kg. for Baltic bottom water (see Fig. 3) — may be satisfactorily explained as due to a moderate hardness of the water in the affluents to the southern Baltic.

Of the 72 calcium analyses recorded in the above-mentioned work by Zarins and Ozolins, 16 analyses of surface water and 6 of bottom water are comparable with the present material. They were collected at Stations 5, 6, and 6a (see the map in the original work) in the open Baltic which we can expect not to be influenced by the water of low salinity and high calcium content in the Bay of Riga. In Table 2 are given analyses of water from the surface layer down to 40 metres at the three stations, and from the bottom layer, from 160 metres downwards, at Station 5. The latter is situated only 2′ south of the Finnish station F81. In addition to depth, chlorinity, and observed calcium content, the table also gives the amount calculated according to Equation 3 for surface water and Equation 1 for bottom water; finally, the last column shows the difference between observed and calculated values.

We see that there is a systematical difference all through, the values of Zarins and Ozolins being in the mean 1·6mg./kg. higher. Plotted against the chlorinities, the surface and bottom values form lines of about the same inclination as those of lines 3 and 1, but lying 1·6mg. higher. There are various possible reasons for this difference. Zarins and Ozolins state that they used double precipitations in determining calcium, but do not further describe their method and do not mention in what kind of glass their samples were preserved. Ordinary glass may give off calcium within a relatively short time. As too high values are the danger of the calcium determination, one is rather inclined to consider the higher results as the less reliable ones. The essential point is, however, that also for the part of the Baltic investigated by Zarins and Ozolins there exist definite relationships between the calcium contents of the surface and of the bottom layers and the chlorinities. Their samples were, moreover, taken on several different cruises, partly in the summer and partly in the late autumn. Zarins and Ozolins, and later von Brandt, attempted to find a relationship by calculating the ratio between the calcium content and the chlorinity. Because of the calcium content of the fresh water with which the Atlantic water becomes diluted in the Baltic, or, in other words, because of the constant term in Equations 1—4, this method cannot lead to the goal. In the Gulf of Bothnia, for instance, for which the closest relationship was found, the ratio varies from 0·0278 at F1 to 0·0264 at F33.

In order to compare von Brandt's results with the present material such analyses were picked out as corresponded to samples collected north of the Finnish station F81. When plotted against the chlorinities most of these were found to lie above the line for surface water in the Baltic and in the Gulf of Finland. As they were, moreover,

very scattered it is to be feared that von Brandt, in making his analyses, did not pay as much attention to the method as might have been desirable.

Relation of Calcium to Excess Base.

A question of considerable interest is that of the relation between calcium content and excess base. Can the deviations from a linear relation in excess base be considered identical with variations in calcium content? As pointed out by von Brandt, the answer for the Baltic is negative. In connexion with the present work excess base and calcium determinations were made on the same water samples. For the first time the method of determining excess base without boiling (Gripenberg (5, 6), Gortikow and Forsch (3)) was applied in duplicate to a greater number of Baltic water samples. The data are not ready for publication, but the very surprising result may be indicated here. In spite of the absolute error of the excess-base determination being about one-third or less of that of the calcium determination, the excess-base values were found to fit much less well to linear relation than the calcium values and, moreover, two analyses of one and the same water sample differed, in many cases, by several units in the second decimal place! In one case a difference of 0·05 meq. per litre was obtained.

As long as the distribution of calcium was unknown, it seemed safe to attribute, as did Buch (2), irregular variations in excess base to the influence of fresh water "alkalinity", i. e., its content of carbonate of lime. Because of the importance of the affluents to the Baltic and their varying hardness such an explanation seemed natural. But now that calcium has proved to be regularly distributed, it does not work any more. We are now obliged to realize that there is in Baltic water an unknown substance, probably in part volatile, which notably influences the excess-base value. Organic acids? The question opens up a wide field of research.

Zusammenfassung.

Analysen des Calciumgehaltes in 48 Proben von Ostseewasser werden beschrieben (Fig. 1). Es wird gezeigt, dass die Verteilung des Calciums in den verschiedenen Teilen der Ostsee durch verschiedene lineare Funktionen des Chlorgehaltes dargestellt werden kann (Fig. 2). Auf Grund der beobachteten Werte wurden vier Gleichungen nach der Methode der kleinsten Quadrate berechnet. Diese gelten für:—

1. Tiefenwasser in der Ostsee,
2. Tiefenwasser im Finnischen Meerbusen,
3. Oberflächenwasser in der Ostsee und im Finnischen Meerbusen,
3. Oberflächen- und Tiefenwasser im Bottnischen Meerbusen.

Das Mittel der Abweichung beträgt 0·4mg./kg. oder weniger als 0·5%. Die vier Gleichungen werden diskutiert, und es wird gezeigt,

dass die Verteilung des Calciums in Übereinstimmung mit bekannten hydrographischen Tatsachen steht. Die Linie für Ostsee-Tiefenwasser schneidet nämlich diejenige für Atlantenwasser bei $Cl = 18{\cdot}8‰$ oder $S = 34‰$, d.h. bei einem Salzgehalt, der in der Nordsee vorkommt, während die drei anderen Linien ganz oberhalb der Linie für Atlantenwasser liegen (Fig. 3). Dies ist auch selbstverständlich, da die Wassermassen, welche von diesen Linien vertreten werden, nicht durch unmittelbare Verdünnung von Atlantenwasser entstanden sind.

Das vorliegende Material wird mit älteren Calcium-Analysen verglichen. Schliesslich wird das Verhältnis des Calciumgehaltes zur Alkalinität diskutiert.

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Variations in Components of Submarine Daylight for 1935 and 1936.

By

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SEASONAL changes in the transmission of some spectral bands of solar radiation in the inshore waters of the Pacific North-West were reported by Williams and Utterback[1]) for the year 1934. These observations have been continued at two stations, Pillar Point and Point No Point, throughout the years 1935 and 1936.

The Pillar Point station, 48°18′N., 124°53′W., is located in the middle of the Strait of Juan de Fuca, twenty-five miles in from Cape Flattery. The characteristics of this station have been described by Thompson, Robinson, and Igelsrud[2]). It is at the head of a submarine chasm which extends through the continental shelf. Due to the turbulence caused by tidal and non-tidal currents on the shelf, much oceanic water is carried into the Straits. The surface layers retain the characteristics of Puget Sound water, however, although it appears greenish blue in colour. The depth is 215 metres.

The characteristics of the water at the second station, Point No Point, are quite different from those existing at Pillar Point. This station is in the main channel of Puget Sound about fifteen miles north of Seattle. Here both organic and suspended matter is much more abundant. The water is of the dark greenish colour typical of inshore waters and the depth is somewhat less than at Pillar Point. Tidal currents are very strong so that mixing of the surface layers at least is almost complete.

Apparatus.

The apparatus has been previously described[1]). Six filters of fairly narrow transmission bands were used. The effective wave-length assigned to each will shift toward the middle part of the spectrum as greater depths are reached because of the greater absorption at the ends of the spectrum. An electromagnet operated a mechanism to rotate the filters above a photronic cell. The current was measured

[1]) E. Allan Williams and C. L. Utterback, J.O.S.A. 25, Dec. (1935).
[2]) T. G. Thompson, R. J. Robinson and Iver Igelsrud, Publications in Oceanography, University of Washington.

Table 1.

Extinction Coefficients per metre at Pillar Point.

Date	$\lambda = 4600$Å. Depth (m.) 0-10	10-20	$\lambda = 4800$Å. Depth (m.) 0-10	10-20	$\lambda = 5150$Å. Depth (m.) 0-10	10-20	$\lambda = 5300$Å. Depth (m.) 0-10	10-20	$\lambda = 5650$Å. Depth (m.) 0-10	10-20	$\lambda = 6000$Å. Depth (m.) 0-10	10-20	$\lambda = 6600$Å. Depth (m.) 0-10	10-20
2· 9·35	·154	·239	·153	·223	·129	·170	·120	·179	·184	·197	·359	·310[1]	·638[2]	—
3·16·35	·241	·149	·223	·188	·190	·149	·210	·141	·257	·159	·410	·328	·492	—
4·20·35	·295	·147	·245	·118	·238	·158	·236	·131	·344	·147	·457	·364	·484	—
5·25·35	·216	·210	·206	·182	·189	·164	·176	·184	·241	·201	·394	·355	·570	—
6·23·35	·230	·201	·221	·092	·151	·167	·212	·081	·223	·141	·360	·309	·698[2]	—
7·25·35	·260	·227	·246	·174	·219	·134	·219	·122	·257	·163	·396	·225	·446	—
9·13·35	·447	·168[1]	·267	·081[1]	·200	·146[1]	·205	·146[1]	·232	·146[1]	·296	·293	·698[2]	—
11·10·35	·147	·126	·120	·119	·108	·104	·112	·109	·195	·102	·357	·318	·455	—
12· 7·35	·147	·149	·115	·132	·108	·144	·120	·112	·183	·184	·327	·304	·454	—
1·18·36	·220	—	·238	·250[1]	·236	·202[1]	·219	·170[1]	·319	·208[1]	·443	—	·622	—
2·22·36	·206	·156	·167	·163	·162	·112	·140	·119	·196	·144	·392	·289	·483	—
3·23·36	·161	·145	·141	·112	·128	·120	·133	·111	·189	·170	·333	·241	·374	—
4·25·36	·188	·144	·171	·138	·151	·128	·171	·121	·210	·162	·381	·393	·798[2]	—
5·23·36	·213	·204	·199	·206	·162	·176	·146	·173	·202	·202	·366	·316	·522	·416[1]
7·14·36	·179	·128	·161	·109	·129	·113	·113	·113	·185	·133	·507	·161	·560	—
8·22·36	·385	—	·318	·304	·299	·332	·215	·315	·272	·285	·437	—	·570	—
9·18·36	·144	·120	·133	·093	·097	·083	·088	·077	·095	·079	·246	·267	·510	—
10·31·36	·157	·106	·131	·092	·112	·065	·119	·067	·123	·074	·323	·256	·421	·390[1]
12· 5·36	·140	·132	·120	·102	·099	·093	·107	·100	·110	·108	·322	·295	·548	—

[1] 10—15 metres only. [2] 0—5 metres only.

by multimeters and by a marine galvanometer which, when balanced, was very satisfactory in even moderately rough seas.

A deck photometer measured the intensity of the light incident on the surface at all times.

Measurements.

Observations were made at monthly intervals throughout the years 1935 and 1936 at each of the two stations. Natural conditions of tide, wind, and surface varied widely from month to month. Although at times fluctuations occurred in the intensity of the incident light, observations were made only when the deck photometer indicated that

Table 2.

Extinction Coefficients per metre at Point No Point.

Date	$\lambda = 4600$Å.		$\lambda = 4800$Å.		$\lambda = 5150$Å.		$\lambda = 5300$Å.		$\lambda = 5650$Å.		$\lambda = 6000$A.		$\lambda = 6600$Å.	
	Depth (m.) 0-10	10-20	Depth (m.) 0-10	10-20	Depth (m.) 0-10	10-20	Depth (m.) 0-10	10-20	Depth (m.) 0-10	10-20	Depth (m.) 0-10	10-20	Depth (m.) 0-10	10-20
2·10·35	·389	·110	·365	·155	·296	·188	·257	·188	·292	·198	·443	·230	·510	—
3·17·35	·365	·170	·313	·173	·271	·356	·245	·211	·368	·154	·417	·274	·680[2]	—
4·21·35	·259	·201	·226	·184	·195	·153	·184	·139	·239	·184	·391	·296	·570	—
5·26·35	·228	·337	·387	·277	·325	·237	·294	·206	·316	·239	·472	·343	·650	—
6·24·35	·366	·283	·331	·230	·259	·228	·227	·204	·270	·212	·422	·350	·645	—
7·28·35	·415	·278[1]	·331	·340[1]	·317	·286[1]	·279	·222	·304	·203	·443	·394[1]	·602	—
9·14·35	·214	·230	·222	·208	·142	·168	·170	·131	·246	·075	·337	·466[1]	·291	—
11· 9·35	·152	·210	·146[2]	·166	·085	·140	·120[2]	·126	·127	·133	·283	·281	·363	—
12· 8·35	·207	·203	·203	·157	·127	·193	·153	·147	·191	·194	·378	·322	·680[2]	—
1·19·36	·275	·110	·238	·184	·233	·161	·197	·271	·263	·148	·384	—	·361	—
2·23·36	·314	—	·232	·161	·204	·188	·197	·132	·256	·144	·402	—	·366	—
3·24·36	·279	·277	·258	·254	·205	·225	·216	·201	·239	·248	·474	·318	·662	—
4·26·36	·386	·300	·322	·295	·309	·204	·247	·246	·328	·207	·458	·403	·617	—
5·24·36	·559	·110	·503	·210	·406	·234	·362	·232	·397	·248	·498	·448	·713	—
6·24·36	·285	·250	·351	·170	·242	·222	·231	·240	·289	·254	·403	·318	·547	·416[1]
7·20·36	·480	—	·405	·374[1]	·352	·277	·310	·252	·328	·282	·534	·496[1]	·826[2]	—
8·21·36	·405	·416[1]	·370	·256	·304	·212	·248	·212	·276	·217	·434	·460[1]	·586	—
9·19·36	·229	·229	·188	·202	·142	·143	·118	·132	·127	·113	·272	·316	·511	·440[1]
11· 1·36	·157	·253	·122	·233	·062	·194	·054	·183	·067	·163	·265	·376	·428	—
12· 6·36	·224	·171	·203	·151	·150	·129	·154	·115	·134	·128	·341	·295	·459	—

[1] 10—15 metres only. [2] 0—5 metres only.

these variations were small. The time required for making a set of observations was seldom more than twenty minutes. It required about three minutes to observe the intensities through the six filters at any one depth. While days on which the sky was overcast were more common (when this was the case, the light coming from all directions was nearly uniform independent of the position of the sun) the effect of the angle of incidence of the light was minimized by taking readings within an hour of maximum altitude during the winter and within an hour and a half during the summer. Observations were made at five-metre intervals beginning just beneath the surface.

Fig. 1. Variations in extinction coefficients for indicated wave-lengths during 1935 and 1936 at Pillar Point station. The mean effective wave-length for curves A is 4800 Å., for curves B is 5300 Å., and for curve C is 6000 Å.

Results.

The values of the vertical extinction coefficients per metre are shown in Table I and Table II. They have been computed for a layer from the surface to 10 metres and from 10 metres to 20 metres, which was the greatest depth at which satisfactory work could be done on cloudy winter days.

The extinction coefficients were computed from the equation

$$I = I_0 e^{-\gamma x}$$

where I_0 is the intensity at one depth, I the intensity x metres deeper, and γ is defined by the equation.

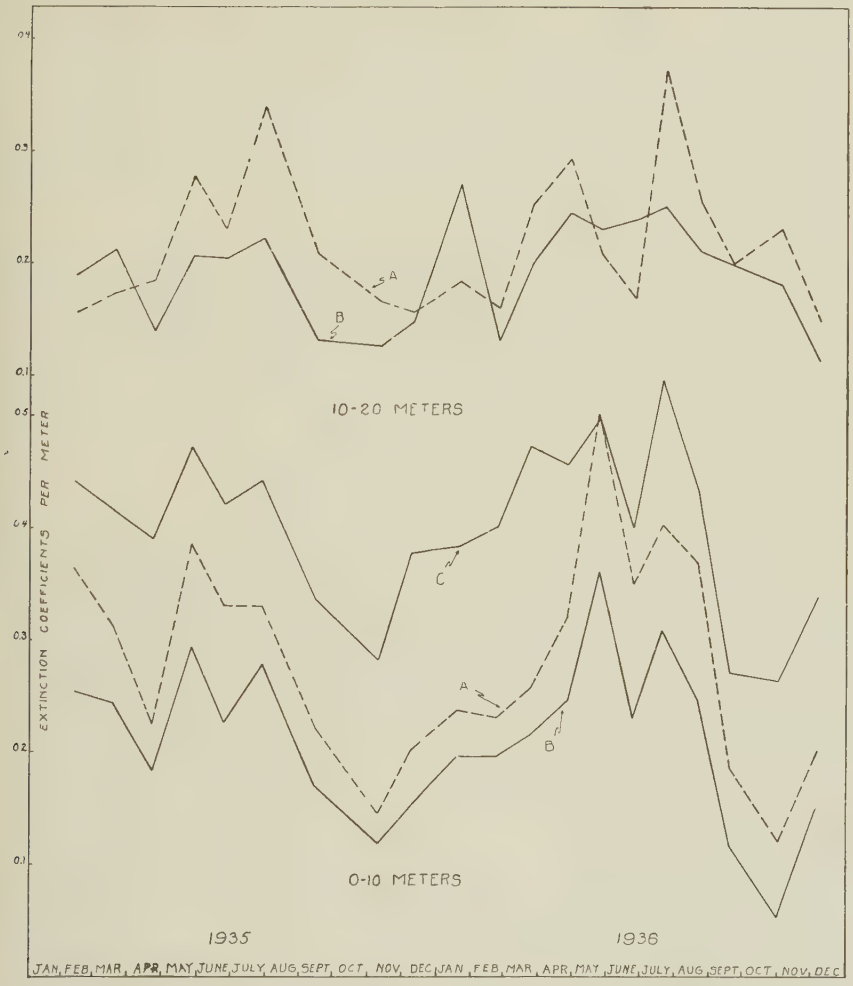

Fig. 2. Variations in extinction coefficients for indicated wave-lengths during 1935 and 1936 at Point No Point station. The mean effective wave-length for curves A is 4800 Å., for curves B is 5300 Å., and for curve C is 6000 Å.

Fig. 1 shows the variations in the extinction coefficients per metre at Pillar Point.

The three lower curves show mean values of these coefficients for the first ten metres. The two upper curves are mean values for 10 to 20 metres. It will be noticed that beginning in February 1935, there was an increase in the coefficients reaching a maximum in the latter part of April. Then there was a slight decrease and a further maximum is reached for the green at the first of August and for the blue a month later. The principal minimum occurs in November and December, after which there is an increase for January of 1936. This year, then,

approximately repeats the behaviour for 1935. The late winter minimum occurs a little later in 1936 and the August maximum is even more marked, but aside from these two features the agreement is very close. Unfortunately, observations were not taken during the late summer of 1934 so that the principal maximum appearing at that time has been verified only during 1935 and 1936. The midwinter and spring maxima and the early winter, late winter, and early summer minima occur in all three years.

The plankton data for 1935 at Pillar Point give a very good qualitative check with these curves. On a comparative scale based on the dry weight of the plankton, the relative abundance was as follows: 1·9 on February 9, 20·2 on March 16, 26·7 on April 20, 21·7 on May 25, 74·9 on September 13, 5·6 for November 10, 4·7 for December 7, and 10·0 for January 8. It is seen that here as before we have maxima on April 25 and September 13 with the principal minimum in December. The relative sizes of the maxima are, however, not comparable in the two sets of data.

In Fig. 2 are shown the variations in the extinction coefficients per metre at the station off Point No Point.

The order of the curves is as in Fig. 1. At this station the curves indicate somewhat different characteristics. They fall to a minimum in the latter part of April just when the Pillar Point curve attained a maximum. They then rise quickly to a maximum in the first part of June, followed by a subsidiary maximum two months later and a minimum in November. The April minimum appears only as a decreased slope in 1936, but the June and August maxima and July minimum are even more strongly marked. Here also the plankton content has a good qualitative correlation with light absorption.

A comparison of these data with those taken a year previously at Hood Canal[1]) is also of interest. The general contours of the two curves are almost exactly the same. The principal maximum is somewhat higher in the more protected waters of Hood Canal and it occurs a month earlier than at Point No Point.

From the greater distance between the 4800 Å. and 5300 Å. curves at Point No Point, it can be seen that the wave-length of maximum transmission has shifted toward the green from its value at Pillar Point. This is what would be expected from the corresponding change in the appearance of the water.

These results are in general a verification of those obtained in 1934. They, in conjunction with those of the previous paper, tend to show that there can be no more than a qualitative correlation between light absorption and total plankton content. While the quantity of organic and inorganic matter in the water is of prime importance in determining the light penetration, the size and the colour of the suspended material will have to be known before a quantitative relationship can be found. Because of the change in efficiency of reflection and scattering with the size of the particle, a direct variation with total quantity could not be expected.

The Distribution of Chaetognatha in Scottish Waters during 1936, with Notes on the Scottish Indicator Species.

By

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FROM February to December 1936 the Scottish research vessel "Explorer" sampled nearly 300 plankton stations from the middle and northern North Sea, the Faroe Channel, and off the north and west coasts of Scotland. Amongst other nets, "cheese-cloth" nets were taken both vertically and horizontally at different depths from the surface to 100 metres and it is on all these 1936 "cheese-cloth" collections that this report is based. It is a preliminary survey until the material collected over a series of years can be analysed and identified.

Seven species or sub-species have so far been identified and each of these is shown to have a significant distribution. I am greatly indebted to Mr. Burfield, of the University of Liverpool, for a very helpful discussion on the literature, classification, and specific characters of the Chaetognatha, and for subsequent confirmation of my identifications which were made from Ritter-Záhony (1911).

Sagitta elegans elegans Verrill (Chart I).

Sagitta elegans is the dominant form in Scottish waters and appears to inhabit chiefly those areas where Atlantic water mixes with coastal water. It was found in 1936 on all Scottish coasts, less frequently on the west coast where the Atlantic influence is very marked, most abundantly in the area immediately south-west of Shetland, and in the Fair Isle Passage, and it was also common off the east Scottish coast and at the Faroes.

The main path of the Atlantic stream lies well off the west coast of Scotland (Tait 1934) and it is chiefly a surface influence that affects the coast. *Velella, Janthina* and other surface oceanic forms

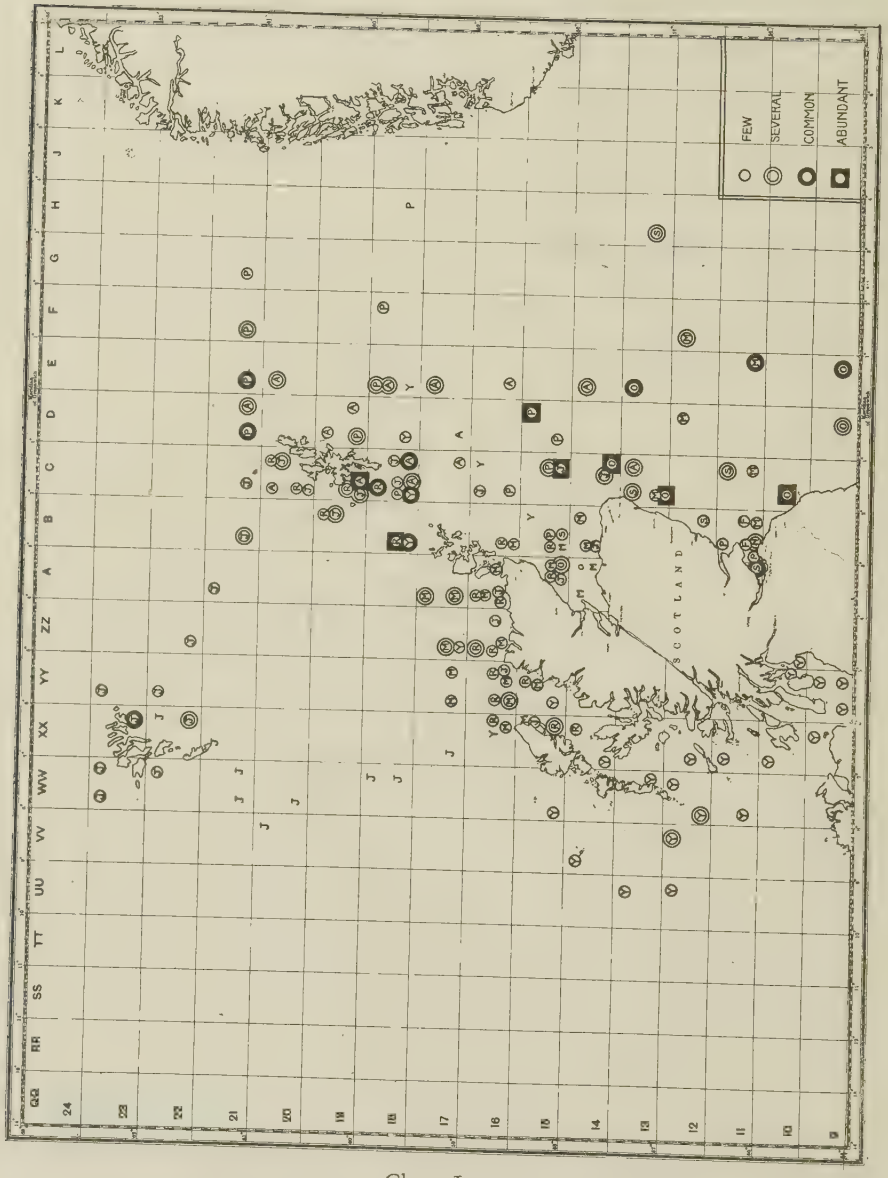

Chart I.
The distribution of *Sagitta elegans* in Scottish waters in 1936.

Each station sampled is indicated by a letter representing the month of sampling, and for convenience is drawn to the nearest sub-area (i.e., an area of ½° longitude and ¼° latitude). The letter has then been ringed according to the numbers of individuals present, an unringed letter indicating absence. The letters used are: F = February, R = March, P = April, M = May, J = June, Y = July, A = August, S = September, O = October, N = November.

are found at times on the coasts (Beatson, Nicol and Elton, 1936), but the sub-surface salps and doliolids rarely penetrate into the inshore waters and bays, even though quite abundant offshore, and deep-water Atlantic forms do not appear to be found there. The path of the main Atlantic stream then passes between Faroe and the Hebrides — an area where, in June, *S. elegans* was completely absent — later passing between Faroe and Shetland where *S. elegans* was scarce, and finally round the north of Shetland, entering the North Sea well to the east of Shetland, thus practically enclosing the dense patches of *S. elegans* in the Shetland neighbourhood. A further dense concentration was found off the Aberdeen coast.

Russell (1935) finds *S. elegans* off the English Channel in a similar environment. There the main source of *S. elegans* is off the south coast of Ireland, an area of "western water" not actually in the main path of Atlantic influx, but influenced by the Atlantic to a great extent, so much so that Russell usually refers to this "western water" as Atlantic water.

S. elegans, however, was absent from the "south-western water" which contains an entirely different plankton, the indicators of *S. elegans* water being absent, and salps, doliolids, *Muggiaea* and *Liriope* present.

By the time the Atlantic stream reaches the Faroe Channel there has already been some considerable admixture of arctic and boreal species presumably of east Icelandic origin. This suggests, from the plankton point of view, a much greater arctic influence west of Faroe than is accounted for by the current-systems depicted by Helland-Hansen and Nansen (1909) and Böhnecke 1931).

The proportion of cold- and warm-water forms varies from year to year, but in 1936 the cold-water forms predominated to a greater extent than usual, especially earlier in the year. The indicators of this water are:— salps, doliolids, *Rhincalanus, Eucalanus, Euchirella, Physophora, Agalmopsis, Diphyes, Galeolaria, Clio pyramidata, Sagitta serratodentata, S. maxima, Eukrohnia hamata, Limacina retroversa, L. helicina, Calanus hyperboreus,* and *Metridia longa.*

As this mixed fauna moves round the north of Scotland the pure warm-water Atlantic forms gradually perish, but there is a further addition of arctic forms between Faroe and Shetland. These, too, gradually perish and the fauna is replaced by a growing admixture of coastal and neritic forms from the Scottish coasts, Shetland and Faroe, and this together with a probable replenishment from the Norwegian Deep south of 61°N. (Gibbons and Fraser, 1937) forms a very rich, often fatty, plankton with abundant *Sagitta elegans, Calanus finmarchicus* and many medusae *(Aglantha, Halopsis, Laodicea, Cosmetira, Tima, Bougainvillia, Neoturris),* and occasionally swarms of *Themisto* and *Limacina retroversa.*

Thus the fauna of the entering Atlantic stream becomes completely changed in quite a short space and time. In exceptionally favourable circumstances a few of the original forms persist and are carried into

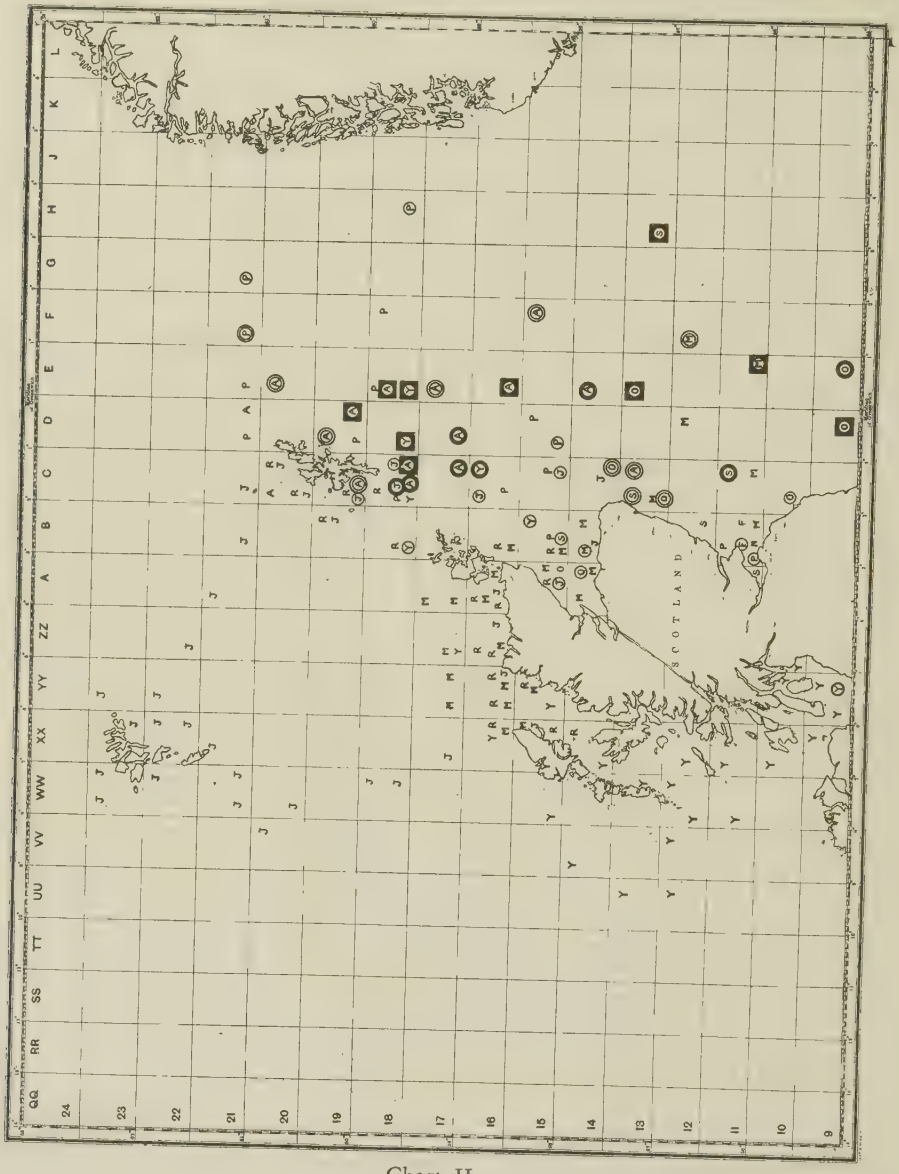

Chart II.
The distribution of *Sagitta setosa* in Scottish waters in 1936. Explanation as in Chart I.

the North Sea as exotics, but as a rule only those forms which are capable of very rapid breeding (such as salps and doliolids in the asexual phase) are found in numbers in the North Sea. Even these persist only in those years when conditions are favourable for their reproduction in Scottish areas (F r a s e r, in preparation).

Thus while an abundance of *S. elegans* on the west coast of Scotland would be rather indicative of the predominance of coastal water, on the east coast and in the North Sea it is indicative of the predominance of Atlantic water. Russell uses *S. elegans* as an indicator of Atlantic water in those areas beyond the normal reach of the warm-water Atlantic fauna *(Liriope, Muggiaea* and *Stephanomia)* and his *S. elegans* is also associated with a very rich plankton often of a fatty nature (1936a). Wimpenny (1936) suggests, too, that *Calanus finmarchicus* and *Sagitta elegans* in the North Sea depend on the influence of oceanic water flowing in from the north.

Sagitta setosa, J. Muller.

Sagitta setosa is recorded as a species indigenous to the North Sea, English Channel, and Irish Sea, and a glance at Chart II shows that its distribution in Scottish waters in 1936 agrees with this. Except for a few specimens found at the northern entrance to the Irish Sea, *S. setosa* was absent from the whole of the west coast, north coast, Faroe and the main Atlantic stream. The few specimens found at the entrance to the Firth of Clyde are doubtless an extension of the fauna of the Irish Sea, and Russell, who also finds *S. setosa* at this point, offers the same explanation. The remainder of the Scottish specimens are confined to North Sea waters, the densest concentrations in 1936 being south-east of Shetland and in the middle North Sea.

In years of strong northerly Atlantic influence North Sea water is pushed further south and the English Channel water further west than in years of weak northerly influence, (Carruthers 1934), so that in years of weak northerly influence, Atlantic water with *S. elegans* is found at Plymouth, and in years of strong northerly influence Channel water with *S. setosa* is found (Russell 1936).

From the biological evidence shown by the plankton the year 1936 was a year of comparatively weak northerly influx and oceanic water ("south-western water") was present at Plymouth (M.B.A. Report for 1936) so that it is probable that *S. setosa* had a more northerly distribution in the North Sea than usual. The northerly limits were, however, so much farther north than suggested by Russell following Scott's distribution of *Centropages hamatus* (Russell 1935, Fig. 6) that it is worth special comment. In 1936 *S. setosa* was found as far north as 61°N. and a few specimens were found in summer on the west side of Sumburgh Head (i.e., just outside the boundary of the North Sea). *S. setosa,* then, is indigenous to the whole North Sea basin and not just to the Southern North Sea or "Bank" water as suggested by Wimpenny (1936). It can, however, be displaced by water containing *S. elegans,* which can be taken as an indication of the penetration of water from a former Atlantic source, or in years of very strong Atlantic influx a more definitely Atlantic fauna may mix with, or even replace, the *S. elegans* in the north-westerly areas. *S. setosa* is outstanding in that there are no very definite indicators associated with it, although young medusae of *Aglantha* and *Obelia*

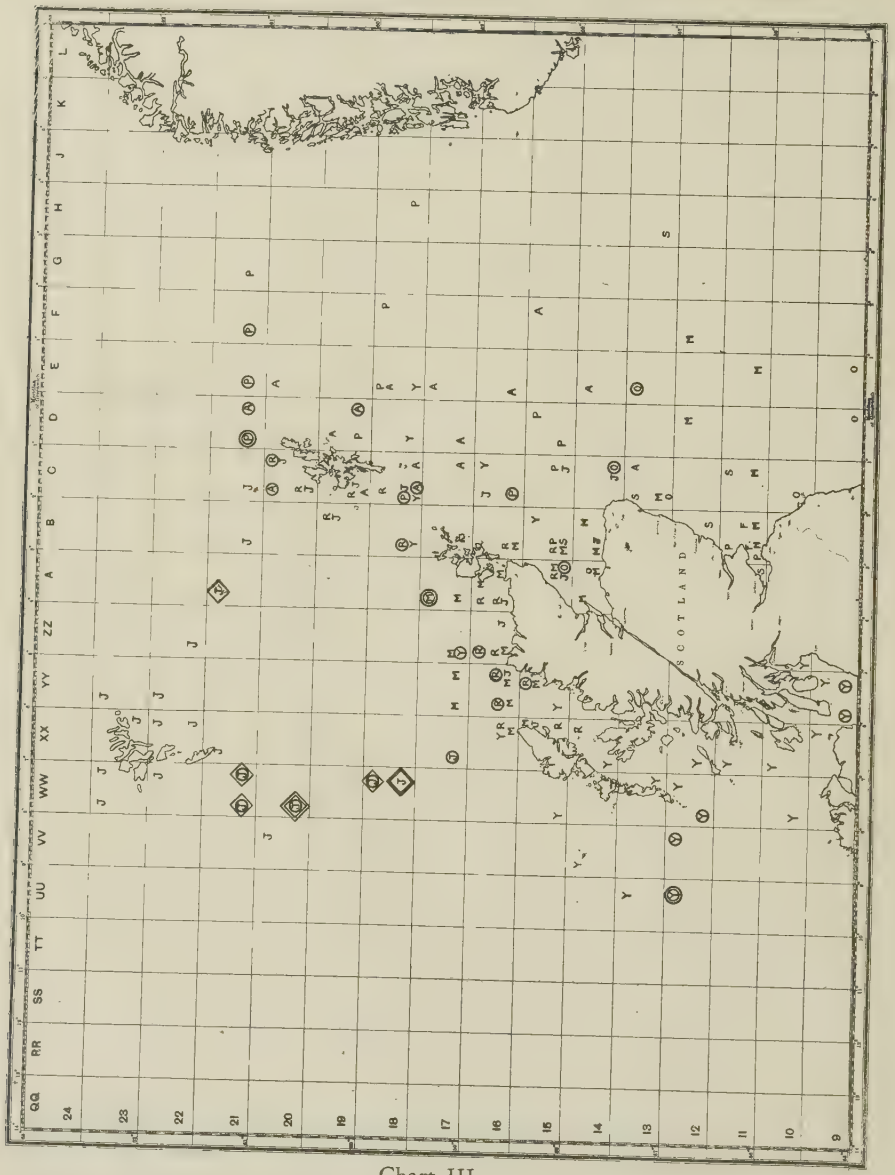

Chart III.

The distribution of *Sagitta serratodentata* (circles) and *Sagitta maxima* (diamonds) in Scottish waters in 1936. Explanation as in Chart I.

often occur. The plankton in association with *S. setosa* is never of a very rich nature.

Sagitta maxima (Conant).

Typical of the oceanic fauna entering the Faroe Channel (i.e., of a mixed Atlantic and arctic origin) is *S. maxima*, a large, transparent,

flabby species, frequently reaching up to and beyond 40mm. in length. It rarely reaches 50mm. although in other areas it has been recorded up to 70mm. (Michael 1911) or 80mm. (Kuhl 1928). This species, although often abundant in the Faroe Channel, always perishes before it is carried very far into the North Sea. In 1936 it was quite common in June on and near the Faroe Bank but was only found at one station between Faroe and Shetland, and even in 1935, although it penetrated in numbers into the Faroe-Shetland Channel, it did not pass far round the north of Scotland. It has been suggested (page 313) that the oceanic fauna largely perishes as it is carried round the north of the British Isles; this in *S. maxima* is probably associated with change in depth. Normally living in deep water beyond the limit of light penetration (600 metres) it is brought into shallow water by upwelling on the edge of the continental shelf and so into an abnormal habitat where it soon perishes.

Kuhl (1928) records isolated specimens in the Norwegian Deep and western Skagerak. Fowler (1896) records *S. maxima* (as *S. whartoni*) from the Faroe Channel. Michael (1911 and 1919) did not separate *S. maxima* from *S. lyra* but they are now generally considered separate species, and Ritter-Záhony (1910b) found both *S. lyra* and *S. maxima* off the Irish coast, but, in 1936 at least, *S. lyra* was not found in Scottish waters.

Sagitta hexaptera d'Orb.

S. hexaptera occurs rarely with *S. maxima*, and is an indicator of Atlantic rather than of mixed Atlantic and arctic water. It is usually confined to the epiplankton of tropical and sub-tropical regions (Ritter-Záhony 1910a), but in higher latitudes it becomes more meso-planktonic. Like *S. maxima* this species perishes soon after being brought into shallow Scottish waters. One or two individuals were taken in the Faroe Channel in 1935, but it was not seen in 1936.

Sagitta serratodentata Krohn.

S. serratodentata is an oceanic form which is essentially epiplanktonic, and so does not suffer to the same extent as the deep-water forms on being brought into shallow water and can persist longer. Its distribution is given in Chart III and shows that although it is not such a good indicator of oceanic waters as *S. maxima*, it is rather more so than *S. elegans*. It does not occur in great numbers like *S. elegans* or *S. setosa*, but is very easy to distinguish with the naked eye by its narrow, rather yellowish, chalky appearance, and when mature by its very large spreading seminal vesicles. It does not appear to breed in the Scottish area; all specimens found have been adults and these have probably been bred out in the Atlantic.

The serrations on the jaws that give this species its name are often very difficult to see, even with an oil-immersion lens. They may be reduced (typically) to a series of very small knobs near the tip of the jaw, or entirely absent, and as most keys to the Chaetognatha separate

this species by this very indistinct and rather unsatisfactory character, it is worth while to describe it as found in Scottish waters.

Body: Typically 15—17mm. in length, narrow and fairly rigid, often rather yellowish, with a chalky appearance.

Collarette: Present, but narrow and reaching almost to ventral ganglion.

Anterior Fin: Reaches to, or almost to, ventral ganglion; widest near posterior end; partially rayed; separated by a short space from, or even confluent with, posterior fin.

Posterior Fin: Widest rather behind tail septum, and slightly more than 50% of its length behind septum; rayed over the greater part of its area; reaches to, or almost to, seminal vesicles.

Seminal Vesicles: Horn-shaped and separated by a small space from tail fin; obvious, even when immature, and one of the easiest ways of spotting the species. Receptaculae seminae fairly well marked.

Ovaries: Long, and often reach as far as, or half way along, ventral ganglion.

Corona: Long and sinuous, extending from between the eyes to about half way to ventral ganglion.

Anterior Teeth: 6.

Posterior Teeth: 13—15.

Seizing Jaws: 5—7. Serrated or tubercled to a varying extent near the tips or sometimes quite smooth, particularly in the more ventral jaws.

Russell, too, uses *S. serratodentata* as a more direct indicator of Atlantic water than *S. elegans* and says (1935, p. 315) "*S. serratodentata* is a pure oceanic species and its occurrence may be taken as an indication that the 'western' water flowing past Plymouth in 1930 was drawn from well out towards the Atlantic." His figure (1935, Fig. 5) illustrating the distribution of *S. serratodentata*, *S. elegans* and *S. setosa* off the north coast of Ireland is confirmed from the Scottish material.

Eukrohnia hamata (Mobius).

Several specimens of *Eukrohnia hamata* have been found, chiefly in the areas off Cape Wrath, and were associated with *S. serratodentata*. It is probable that *E. hamata* has a similar indicator value to *S. serratodentata* except that it is mesoplanktonic instead of epiplanktonic. It is not, however, so abundant off the Scottish coasts (at least it was not in 1936) as one would expect from its abundance off the Irish coasts (Ritter-Záhony 1910b). Like other oceanic mesoplanktonic forms it does not persist long in the shallower waters.

Sagitta elegans arctica Aurivillus.

A thriving community of *S. elegans arctica* was found in the Firth of Forth in November 1936, to the almost entire exclusion of *S. elegans*

and *S. setosa*. There is very little clear-cut difference between the varieties of *S. elegans*, as all have similar arrangements of fins, ventral ganglion, seminal vesicles, corona ciliata, head armature and gut diverticulae: differences occur which overlap considerably on either side so that a complete sequence of types from typical *elegans* to typical *arctica* can be found. Those in the Firth of Forth in November, however, were definitely typical *arctica*, and could be separated at once by naked eye owing to their larger size and very opaque white nature; they had a very well-developed collarette.

This community is further evidence that the Firth of Forth is a biological unit separated from the North Sea immediately outside the Firth, as has already been suggested by Dr. Gibbons (unpublished) from a study of the *Calanus* and *Anomalocera* populations. *S. elegans arctica* has not been found immediately outside the Firth where *S. elegans elegans* is abundant. It is evident, however, that this was only a passing community, as there was no trace of *arctica* in the Firth in July 1937, nor were there any there during September or November af 1935, nor any specimens obviously *arctica* in February or April 1936. Those found in November 1936 were quite large specimens but were not mature. Probably a few specimens had reached the Firth and had multiplied there to form a temporary community, later dying out, but lack of Firth of Forth material during an extended period makes it impossible to follow the cycle. It will be of interest to see if there is any recurrence of this species. It is noteworthy, in this connexion, that Burfield found *S. elegans arctica* only in the shallower water of Hudson Bay.

So far, *S. elegans baltica* has not been identified from Scottish waters.

Summary.

A study has been made of the distribution of the species of Chaetognatha in Scottish waters during 1936, and these Scottish results supplement those of other workers and so help to complete the picture of the European distribution. Where the results overlap, almost complete agreement is found.

S. elegans is found to belong to the mixed oceanic and coastal water. It is found on all west and north Scottish coasts, Shetland and Faroe, and as far into the North Sea as the oceanic influence comes. It is shown that the fauna of the entering Atlantic stream becomes completely changed in a short time and space from a warm-water fauna to a mixture of cold- and warm-water forms and finally to a rich coastal fauna with a few of the original warm-water and cold-water species as exotics.

S. setosa is found to belong to the whole North Sea basin and may extend as far north as 61°N. It is displaced by *S. elegans* where there is an oceanic influence.

S. serratodentata is more truly oceanic, and being a surface form is an excellent "indicator" of surface currents.

S. maxima belongs to the deeper oceanic waters. It is carried into the Faroe Channel by currents and brought to the surface by upwelling on the edge of the continental shelf where it soon perishes.

S. hexaptera probably occurs only in years of strong warm Atlantic influence. Like *S. maxima* it is not long-lived in Scottish waters.

E. hamata, like *S. serratodentata,* is an oceanic form of more general distribution, but belongs to a slightly deeper habitat.

A community of *S. elegans arctica* was found in the Firth of Forth in November.

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A Quantitative Method for the Experimental Study of Plankton Diatoms.

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MARINE plankton diatoms were first studied under laboratory conditions by Allen and Nelson (1910). These workers succeeded in growing many of the more important species in "persistent cultures", i.e., with only one single species of algae in each culture, which was not, however, necessarily free from bacteria and minute flagellates. Natural sea water to which were added phosphate, nitrate, iron and calcium compounds according to Miquel's prescription (Miquel 1890—93) was found to be a good culture medium for these organisms. Cultures in artificial sea water as a rule showed no proliferation at all. The persistent cultures were mostly obtained by the dilution method, with only occasional success in isolating single cells or chains by picking them out with a capillary, as did Miquel with freshwater diatoms (*l.c.*). The main purpose of Allen and Nelson's study was to find conditions in which planktonic diatoms would grow so well that cultures of such species could be used for feeding larvae. Their work was therefore confined to qualitative studies, the rate of growth being estimated by the macroscopical appearance of the cultures. For feeding purposes this method has proved very useful.

Allen continued his interesting studies, trying to replace the miqueled sea water with artificial sea water. He did not, however, succeed in making a purely synthetic culture medium which was satisfactory. An addition of as little as 1% (boiled) sea water was necessary to obtain a good growth in the artificial medium. (Allen 1914).

Several years later Schreiber (1927) continued the investigations of marine plankton diatoms, in order to trace the relationship between the plankton organisms and their environment. For this purpose he worked out a *quantitative* method for the study of persistent diatom

cultures[1]). Into dishes with sterile nutrient solutions he introduced single cells of the organisms to be studied. The dishes (Esmarck dishes) were kept on a rack in controlled light and temperature conditions. In this way Schreiber was able to determine the rate of multiplication of large neritic diatoms (species of *Biddulphia*) in well-defined light and temperature conditions. His results are the only quantitative experimental data on the biology of true planktonic diatoms. The method does not, however, seem to be suitable for a general study of most plankton diatoms (see below).

Besides these basic studies on persistent cultures of these forms, we may mention a method which Gran (1918) worked out for mixed plankton cultures. Bottles were suspended at different depths in the sea and the change in the quantity of plankton in them was studied for different nutrient conditions (light, nutrient solution). Marshall and Orr (1928) applied this method to persistent cultures of *Coscinosira polychorda* for a study of its photosynthesis at various depths.

Persistent cultures of the littoral diatom *Nitzschia closterium* have been the object of interesting special studies by Atkins (1923), Stanbury (1931), and Harvey (1933). Their methods may be applicable also to the study of true plankton forms.

By the quantitative phytoplankton determinations (centrifuging or sedimentation) one can trace changes in the *numbers* of the various phytoplankton organisms of a water mass. For an interpretation of these changes in view of the biology of the different species it would seem especially desirable to obtain data on their rate of multiplication in various environments.

Schreiber's method (*l.c.*) has proved to be useful in some cases for obtaining such information. However, the lack of circulation in the fluid, which leaves open the possibility that local deficiency in some compounds may occur, and also that locally the cells may be heated more than the surrounding water, seems to be a drawback which would impede its general application for the purpose in question.

An ideal method for the study of the biology of plankton diatoms would have to fulfill the following requirements:— 1) The use of bacteria-free pure cultures, 2) controlled variation of temperature, light, and nutrition within a fairly large range, and 3) a quantitative procedure of work. So far the little work we have had an opportunity to do towards this goal has been confined to an attempt at working out a method which would to some extent fulfill the last two requirements. If this should succeed, the method might probably be applied to bacteria-free cultures as well.

During the summer of 1930 some preliminary experiments on

[1]) Although Schreiber *(l.c.)* was able to obtain absolutely pure cultures (or bacteria-free cultures) of green flagellates, he did not succeed in freeing the diatoms from all the bacteria.

quantitative work with persistent cultures were carried out at Bergens Museum's Biological Station at Herdla. Gran's method of 1918 was used, but with persistent cultures (according to Allen and Nelson) instead of raw plankton, in the same way as did Marshall and Orr (1928). The results obtained in parallel cultures did not, however, accord satisfactorily, for several reasons. Partly the circulation in the bottles was insufficient, partly interferences occurred in connexion with the suspension of the bottles, and also the cultures were too dense.

On the basis of these experiences the work was continued in 1935, during a 4½ months visit to the Zoophysiological Laboratory in Copenhagen. As experiments of this kind take a rather long time before they give results, only a few could be carried out during this visit. Nevertheless they seem sufficient to show that work with a method similar to that used here ought to give valuable information on the biology of plankton diatoms. We find it, therefore, justifiable to give an account of the method which we have used.

Qualitative Cultures.

In order to have material for the quantitative experiments persistent cultures of the following plankton diatoms were started in miqueled sea water (Allen and Nelson, *l.c.*):—

Chaetoceros curvisetus, Ch. laciniosus, Ch. simplex, Coscinodiscus excentricus, Eucampia zoodiacus, Porosira glacialis, Sceletonema costatum, and *Thalassiosira Nordenskiøldi.*

They were all isolated from a net-haul sample collected at the surface in the Øresund, Jan. 23rd (salinity 12·93‰, temperature about 2°C.).

Dilution cultures according to Allen and Nelson gave persistent cultures of *Sceletonema* only, the most abundant species in the sample. All the others were isolated by means of capillary tubes, under low power. By transference through at least 6 drops of sterile nutrient solution and consistent control under the microscope they were freed from other algae. Occasionally small *Chaetoceros* species (*simplex* and *subtilis*) contaminated all the cultures of a species. This was the case with *Asterionella japonica,* which showed a good growth mixed with *Ch. simplex*[1]). The isolation was carried out in a cool room (5—10°C.). After the isolation the flasks were placed in a window with no direct sunlight, at a temperature between 5 and 10°C., with slow changes only. Later they were transferred to aquaria with running water at 10—12°C., by a window which was lime-washed to avoid direct sunlight. (Cultures of plankton diatoms exposed to direct sunlight died, even after an exposure of less than an hour, while littoral species can stand such exposure for hours).

After a few weeks the cultures showed signs of "ageing" similar to those observed by Allen and Nelson (*l.c.*). Bacteria became

[1]) It is advisable always to make several isolations of each species in order to be certain of getting some successful persistent cultures.

very numerous indeed, and the diatoms were infected by parasites, sometimes so badly that most of the cells died. Especially the old cultures of the two *Chaetoceros* species, *curvisetus* and *laciniosus*, suffered badly from such infections. *Ch. laciniosus* once responded to the unfavourable conditions with the formation of regular resting spores. In most cases, however, the cells became quite different from those met in nature. The chromatophores turned dark brown, a brownish-red body occurred beside them, and the rest of the cell content was highly refractive on account of the accumulated fatty oils. Many of the cells died. Similar dark-brown cells were formed in *Ch. curvisetus* cultures. After some weeks such cultures were rejuvenated, normal cells appearing again. The transition from resting to normal cells seems to go by way of auxospores. Observations on cultures in hanging drops, intended to give information on this matter, did not, however, give any conclusive proof that this is always the case. In *Sceletonema* the ageing phenomenon was always connected with a shortening of the silica rods which normally produce intervals between the cells of at least a cell's length. This reduction of the rods seems to be caused by a deficiency in available silica in the cultures. An account of some simple experiments with regard to this question is given elsewhere. In *Thalassiosira Nordenskiøldi* the distance between the cells (which in this species are kept together by a mucilaginous string) likewise became shorter in old cultures. The chromatophores turned dark brown and the cell content became highly refractive.

When transferred to fresh nutrient solution, *Sceletonema, Thalassiosira,* and *Porosira* always became normal, while the *Chaetoceros* species and *Eucampia* were sometimes so infected that they did not recover by transference, although the old cultures eventually became normal in appearance again.

For quantitative experiments fresh cultures in the same medium as used in the experiments were used. It is so imperative for a good result in quantitative studies to have healthy and not too dense cultures for infection that it would seem recommendable in future work to carry out routine transference of the cultures, at short intervals of time only (say 1½—2 weeks). The importance of this point was not fully realized in the first experiments, a fact which caused some delay.

A l l e n and N e l s o n (*l.c.*) found that the plankton diatoms were able to grow within a large range of salinities, viz., from a few per mille to more than the values usually found in the sea. In order to obtain an idea of how sensitive these organisms are to sudden changes in the salinity of the medium, we made a few simple experiments with *Eucampia, Sceletonema,* and *Thalassiosira Nordenskiøldi.* The last two species were transferred from 20‰ water directly to 15, 10, and 5‰ water. A reduction of 5 and 10‰ in the salinity did not seem to hurt the cells at all, while after the transference from 20 to 5‰ water some of the cells of both species died. Other cells survived, however, so that after a week the culture showed good growth with normal cells. A rise of 10‰, likewise, did not seem to hurt the

cultures noticeably (microscopical examination at intervals during the first 24 hours, daily examination for the rest of the time). Similar experiments with *Eucampia* gave the same results, though some of the cells died when transferred from 20 to 30‰ water, but this culture also eventually throve well at a salinity of 30‰. Higher salinities were not used.

The cultures of these boreal forms all survived at temperatures as high as 17—18°C., the highest to which they were exposed. *Sceletonema* was once transferred to a room at 20 to 25°C., and showed fair growth at this temperature.

The Method for Quantitative Experiments.

To determine the rate of multiplication in planktonic diatoms in various environmental conditions we wanted an apparatus where, first, a fairly large number of culture bottles could be kept under the same conditions, second, where water circulation in and outside the flasks would secure uniform, controllable temperature conditions, and, third, where the lighting arrangement gave uniform light conditions for all flasks and would allow changes in the light-intensities. Under the supervision of Professor K r o g h an apparatus for this purpose was made in the machine shop of the Zoophysiological Laboratory. (Figs. 1 and 2).

The bottles used were wide-mouthed 50c.c. Jena glass bottles, 7·5cm. high, covered with a dish 1·7cm. high. These were placed in a wooden frame, divided into 10 compartments by means of wooden rods. Each compartment held 9 flasks, which were kept in place by strips of lead glass over each row. The frame was so placed in an aquarium with running water that the water level reached halfway up the bottles. The frame was suspended by 4 arms, which were bolted to 4 posts on the aquarium (see figures). A water-driven motor moved the frame slowly back and forth, with a jerk at each turnover of the motor. In this way sufficient circulation was produced. The temperature in the bottles was found to be practically identical with that of the outside water, even when high light-intensities were used.

The lighting arrangement consisted of ten 25-watt bulbs, 25cm. long, mounted in 5 rows on a board which was placed on cross-bars between the 4 posts on the aquarium. Each row could be lighted independently. The cross-bars could be placed in several positions so that work at different light-intensities could easily be arranged. A light-blue filter (a sheet of Diophane Light Blue) was used. At the higher light-intensities without such a filter *Sceletonema* developed cells which were different from those found in nature. The cells were larger and the chromatophores pale. When a filter was used they had a normal appearance. Abnormal cultures changed into normal ones when transferred to daylight or artificial light with a filter. Diophane is not well suited as a filter, as it fades fairly quickly. We used it in these experiments because we wanted to have the same conditions for all in order to obtain results mutually comparable. Coloured glass or

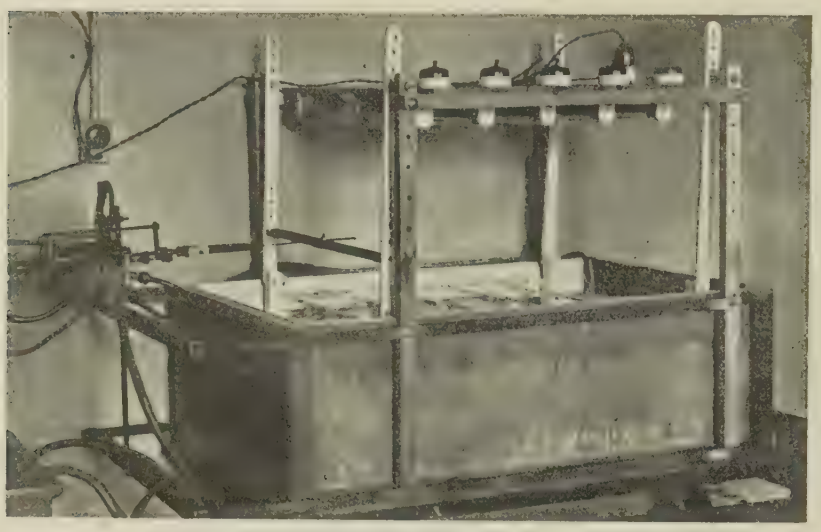

Fig. 1.

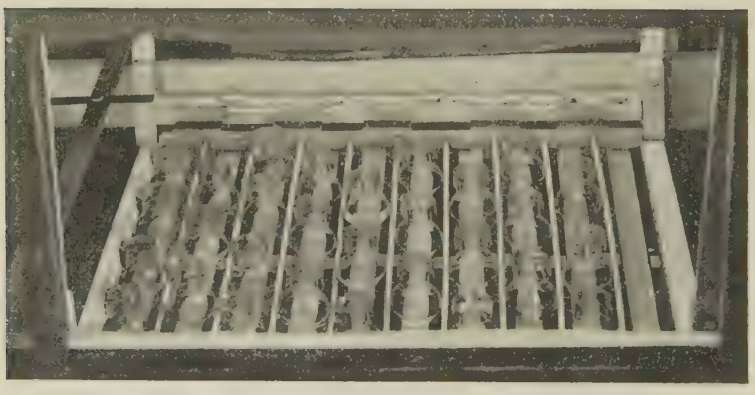

Fig. 2.

a thin cuvette with copper sulphate may serve the purpose better. Light measurements were carried out with a Photron photometer.

The daylight was kept away by means of a black cloth on the window side of the aquarium. The scattered light reflected from the walls in the room represented less than 100 lux at noon.

The aquarium was painted white inside. During the last experiments a lively growth of freshwater diatoms occurred, and under such conditions it would have been better to have the inside painted black in order to have as uniform light conditions as possible. It would seem most convenient to have the apparatus in a dark room.

The procedure which we adopted for quantitative experiments in this apparatus was as follows.

From a persistent culture in good growth, without any abnormal signs or any noticeable attack of parasites, a small drop was transferred to a drop of sterile nutrient solution on a slide. The organisms in this drop were carefully counted (without cover-glass) and the drop transferred quantitatively, with several rinsings, to a culture flask with sterile nutrient solution. This transference and the counting were done at a temperature as close as possible to that of the experiment to be carried out. During the later part of spring, the slide was cooled by a small chamber through which water cooled by ice was circulated.

When the experiment was terminated the content of each culture flask was preserved by addition of 1cc. 2% neutralized formaldehyde, and by addition of distilled water brought up to a certain volume. Direct counts were made of variable fractions according to the density of the culture, at least 5 different counts from each.

Tables 1 to 3 show the results of the first experiments.

Table 1.

Sceletonema costatum. February 25th to March 6th.
Salinity: 19·88‰, Temperature: 9—10°C., Miquel sea water.

Initial number	508	587	700	1708	3323
Final number	75,950	89,945	394,300	807,200	1,274,700
One cell has multiplied to..	150	153	549	472	384
Total number of fissions ..	7·2	7·3	9·1	8·9	8·6
Average number of fissions per 24 hours	0·9	0·9	1·1	1·1	1·1
Duration of experiment ...	8 days	8 days	8 days	8 days	8 days
Light conditions.....	Not screened		Continuous artificial light of about 800 lux		
Amount of fluid	30c.c.	30c.c.	30c.c.	30c.c.	30c.c.

Good growth had taken place in all the bottles, but the rates were too different. In *Sceletonema,* for example, the average number of cell divisions per 24 hours varied from 0·9 to 1·1, and in *Chaetoceros laciniosus* the variations were still greater. In these experiments the light board was placed at the maximum distance, so that the artificial light supply was low, about 800 lux. Daylight entered from the side, and although the apparatus was placed at a distance of 4·5m. from the window the daylight supply was considerable. The various flasks received a different amount of daylight in addition to the artificial light, a fact which we held responsible for some part of the differences in the rate of growth within parallel cultures.

A black cloth was therefore used as a screen during subsequent experiments. Other factors also seemed to have interfered and to be partly responsible for these uneven results. In the tables the parallel cultures have been recorded in sequence according to their initial number of cells. In the case of *Chaetoceros laciniosus* the average rate

Table 2.

Chaetoceros laciniosus. February 26th to March 11th.
Salinity: 19·88‰, Temperature: 9—10 °C., Miquel sea water.

Initial number	7	247	355	782	854
Final number	3,325	21,525	11,375	40,705	12,250
One cell has multiplied to	475	87	32	52	14
Total number of fissions.	8·9	6·4	5·0	5·7	3·8
Average number of fissions per 24 hours	0·86	0·62	0·48	0·55	0·37
Duration of experiment	10·3 days	10·3 days	10·3 days	10 days	10·3 days
Light conditions	Not screened		Continuous artificial light of about 800 lux		
Amount of fluid	30c.c.	30c.c.	30c.c.	30c.c.	30c.c.

Table 3.

Chaetoceros curvisetus. February 28th to March 11th.
Salinity: 19·88‰, Temperature: 9—10°C., Miquel sea water.

Initial number	22	64	87
Final number	4,960	17,500	35,700
One cell has multiplied to	225	273	411
Total number of fissions	7·8	8·1	8·7
Average number of fissions per 24 hours	0·93	0·96	1·0
Duration of experiment	8·4 days	8·4 days	8·4 days
Light conditions	Not screened	Continuous artificial light of about 800 lux	
Amount of fluid	30c.c	30c.c.	30c.c.

Table 4.

Thalassiosira Nordenskiøldi. March 29th to April 5th.
Salinity: 19 88‰, Temperature: 9—10°C., Miquel sea water.

Initial number	50	77	111	162
Final number	62,250	91,110	44,000	60,900
One cell has multiplied to	1,245	1,182	396	376
Total number of fissions	10·3	10·2	8·6	8·5
Average number of fissions per 24 hours	1·4	1·4	1·2	1·2
Duration of experiment	7·2 days	7·2 days	7·2 days	7.2 days
Light conditions	Screened	Continuous artificial light of 1500 lux		
Amount of fluid	25c.c.	25c.c.	25c.c.	25c.c.

of multiplication was higher in those flasks where the initial numbers were small than in those where it was large. This would indicate that the growth is quicker while the population is small and then falls off as the culture gets denser. In the *Sceletonema* cultures this is not the case; the effect of the unevenness in the light distribution may here have overshadowed the influence of the other factor. In the later experiment

(Table 5) with improved lighting arrangements, *Thalassiosira Nordenskiøldi* clearly shows the decrease in the average rate of multiplication with increasing initial numbers. The highest rates in both experiments were recorded for the bottles with low initial numbers in the same way as indicated in the *Chaetoceros laciniosus* experiment mentioned above.

Table 5.

Thalassiosira Nordenskiøldi. April 17th to 30th.
Salinity: 20‰. Temperature: 10—11°C., Miquel sea water.

Initial number	2	3	4	7	37	57
Final number	115,780	175,350	101,600	292,600	359,450	415,800
One cell has multiplied to	57,890	58,450	25,400	41,800	9,715	7,295
Total number of fissions	15·8	15·8	14·6	15·4	13·2	12·8
Average number of fissions per 24 hours	1·2	1·2	1·1	1·2	1·0	1·0
Duration of experiment	13 days	13 days	13 days	13 days	13 days	13 days
Light conditions	Screened		Continuous artificial light of 1500 lux			
Amount of fluid	25c.c.	25c.c.	25c.c.	25c.c.	25c.c.	25c.c.

In the first *Thalassiosira* experiment (Table 4), where the final numbers were less than 100,000, the average proliferation was slightly higher than in the second experiment where the final numbers were considerably higher, viz. 100,000—400,000 (Table 5). The sea waters used for nutrient solutions were different. It is therefore possible that although they were both miqueled, some difference in their composition may have caused the slight difference in proliferation. In view of the fact that these plankton organisms have been found to be very capricious in their behaviour when cultured (cf. Allen and Nelson 1910, Schreiber 1927) the method seems to give reliable results when certain precautions are taken. In our experiments we used only about 25—30c.c. nutrient solution. It would seem better to increase this amount and still use as low numbers as possible in order not to get too dense a population. We let the experiments go on for so long a period of time that we could make direct counts, but one might just as well make counts of less dense cultures by means of centrifuging or sedimentation. A fairly long time would, however, seem desirable to get a representative average for the rate of multiplication.

Since time allowed these few experiments only, we worked with only two different light-intensities, and did not try variations in the light-quality. For such experiments this apparatus would, however, seem suitable.

Concluding Remarks.

The experiments described above were intended to show whether the method gave reliable results in parallel cultures. Nevertheless, these few data also give, as we shall see, an indication of what one may hope to achieve by continued work along these lines.

One of the aims of experimental biology is to find the physiological background for ecological observations and ecological classification. The plankton diatoms have been the subject of such classification, first by C l e v e (1900), later, on a more biological basis, by G r a n (1902). These groups were based on the temperature conditions of the habitats of the species and they suggested different temperature requirements of the arctic, boreal, temperate and tropical species. One of the most important spring diatoms in northern coastal water, *Thalassiosira Nordenskiøldi*, was referred to the boreal (neritic) plankton element (G r a n 1902). It occurs in huge quantities just after the temperature minimum of the waters has passed. The mean temperature at which it was recorded in Danish waters was 2·3° (O s t e n f e l d 1913). In the Bay of Fundy G r a n and B r a a r u d (1935) found it to have a spring maximum, similar to that observed in northern European waters, although for various reasons it was there somewhat belated. *Thalassiosira Nordenskiöldi* (and its companions, like *Porosira glacialis)* disappeared from the surface layers when these reached a temperature of 5—6°C., although the surface layers still did not seem to be exhausted of their supply of nutrient salts. G r a n and B r a a r u d (1935) found that the distribution of this species was such as to suggest that its proliferation at temperatures above 5—6°C. would be very slow.

Sceletonema costatum is another important spring diatom in northern European waters. It does, however, also occur in the autumn, often in considerable quantities; it belongs to the diacmic species (O s t e n f e l d 1913). In late summer it occurs at temperatures (10—12°C.) which are considerably higher than those prevailing at its spring maximum. Accordingly one would be justified in considering it as being eurythermal, depending little upon the temperature of the habitat.

In these experiments we have grown both species at temperatures of 10—12°C. It seems to accord well with the ecological observations that *Sceletonema* thrives well and multiplies at a good rate at this temperature (Table 6). It is, however, unexpected to find that *Thalassiosira Nordenskiøldi* has a similar, if not higher, rate of multiplication at 10—12°C. than has *Sceletonema* (Table 4—5).

This gives only an indication that our conclusions, based upon the records of the distribution of the various plankton diatoms, may have to be revised if we can obtain more experimental data on their biology. In the cases of *Thalassiosira Nordenskiøldi* and *Sceletonema costatum* it would seem probable that the rate of multiplication in the two species would vary differently according to the concentration of nutrient salts. *Sceletonema* being a much smaller species than *Thalassiosira Nordenskiøldi* and accordingly with a much larger relative surface, one would expect the latter to respond more in its rate of proliferation to changes in the nutrient salt supply than *Sceletonema.*

We have only single observations on the rate of multiplication in species other than those mentioned above, viz., in *Eucampia zoodiacus* and *Porosira glacialis* (Table 7).

Table 6.

Sceletonema costatum. April 17th to 30th.
Salinity: 19·88‰, Temperature: 10—11°C., Miquel sea water + soil extract.

Initial number	8	19
Final number	425,075	620,200
One cell has multiplied to	53,134	32,642
Total number of fissions	15·7	15·0
Average number of fissions per 24 hours	1·2	1·2
Duration of experiment	13 days	13 days
Light conditions	Screened	Continuous artificial light of 1500 lux
Amount of fluid	25c.c.	25c.c.

Table 7.

	Eucampia zoodiacus. Feb. 28th to March 11th. Miquel sea water. Salinity: 20‰, Temp. 9—10°C.	*Porosira glacialis.* April 17th to 30th. Schreiber sea water. Salinity: 12·69‰, Temp. 10—11°
Initial number	1,073	60
Final number	78,400	2,363
One cell has multiplied to	73	39
Total number of fissions	6·1	5·3
Average number of fissions per 24 hours	0·72	0·4
Duration of experiment	8·4 days	13 days
Light conditions	As in Table 1	Screened
Amount of fluid	30c.c.	25c.c.

Eucampia was grown under the same conditions as *Sceletonema* in the experiment to which Table 1 refers. It showed a lower rate of multiplication than any of the *Sceletonema* cultures, viz., 0·72 fissions per 24 hours of light. *Porosira glacialis,* a regular companion of *Thalassiosira Nordenskiøldi* in spring, was grown in the same conditions as this species (Table 7). It had an average rate of multiplication of 0·4 fissions per 24 hours, while *Thalassiosira,* even in its dense cultures, had 1·0 fission per 24 hours (cf. Table 5). These results are in agreement with the occurrence of these species in nature. *Eucampia* and *Porosira* are never found in such quantities as *Sceletonema* and *Thalassiosira Nordenskiøldi.*

The fact that *Chaetoceros curvisetus* proliferates almost as fast as *Sceletonema* and *Thalassiosira* under the same conditions, while *Chaetoceros laciniosus* grows somewhat slower, would also seem to agree well with their relative maximum abundance in their occurrence in nature.

However, these data are obviously too few for any further discussion of the question. Only when the changes in the rate of proliferation according to temperature, light, and other environmental conditions have been studied in more detail shall we be justified in

applying the results to the interpretation of the relative distributions of the species.

In conclusion, I wish to express my sincere thanks to Professor Dr. August Krogh for his hospitality in according me the advantage of the excellent accomodation of his laboratory, and for his advice and interest during my work there.

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Two Technical Notes.

By

H. J. Buchanan-Wollaston,
Fisheries Laboratory, Lowestoft.

(1) Estimating the Depth at which Horizontal Hauls are Made.

THE method described below gives reasonably accurate estimates of the depth at which one or any number of horizontally towed nets or other apparatus are working, provided that the speed of the ship through the water be kept constant during shooting and towing. The method has been in use for some years but is certainly not universally known.

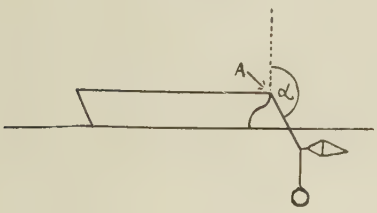


Fig. 1.

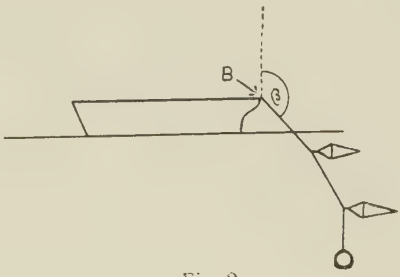


Fig. 2.

The lowest net is attached to the towing line, and sunk to a depth so small that the part of the line between ship and net may be considered straight. One of the angles, α or α—90° or 180°—α in Fig. 1 is measured by any convenient apparatus.

Now, the forces acting on this section of line, net, and weight are the same at whatever depth the section is working, neglecting the very slight change due to increasing density of water with increasing depth and the very small error due to the upper end of the line being out of water. Thus the depth of the net below A will remain constant, however deep A may be sunk.

Another net being now attached, as in Fig. 2, and a further section of line paid out, the angle β is measured, and the section AB will now, if paid out, retain its position relative to the vertical and horizontal, i.e., the depth of the second net below B will remain constant at $r \sin (\beta - 90°)$ where $r =$ length of line between net and point of measured angle. In this way, and by measuring the angle of the line at intervals between the nets, the depth at which each net is working may be very simply calculated with only a quite inconsiderable error.

(2) Estimating the Total or the Mean Number of Organisms under a given Area of Sea or on a given Area of Sea Bottom.

The method of contours gives the most graphic picture of the distribution of organisms, but it is not the most convenient or the most accurate method of obtaining their total quantity. The following method is preferable.

Each station is considered as representing the area of a circle of which the diameter is the mean of all the distances between that station and immediately adjacent stations. Half this mean distance, squared, is allotted as a weight to the count of organisms at the station. The total of all weighted counts is not, of course, the absolute total, but is approximately proportional to it and is comparable with other totals similarly obtained. The mean density of organisms, obtained by dividing the total by the sum of the weights, is comparable with other mean densities, no matter how different the areas compared may be. The circular areas may be expressed in any convenient units.

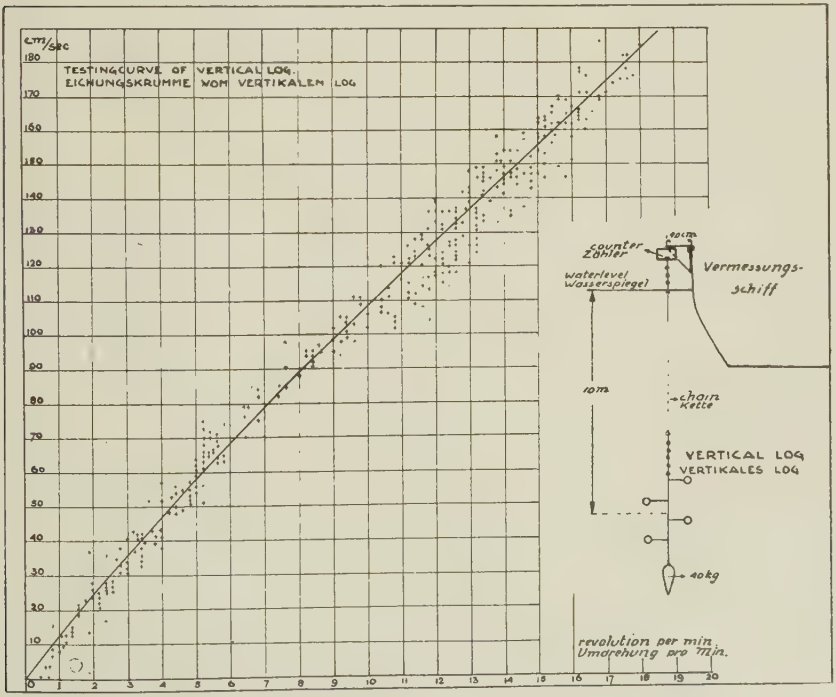
Increased accuracy of estimates may be obtained by dividing up the area completely into irregular figures of which the areas are obtained by means of a planimeter or with squared paper. This division, however, has an arbitrary element, influenced by the "personal equation", and is on that count objectionable.

Letter to the Editor.

Sir,

The following information regarding continued stream observations on the Dutch lightvessels may be of interest.

A series of observations will be made on board the Dutch lightships in order to obtain accurate information about the periodic or non-periodic changes in the drift along the Dutch coast, and also to check the results obtained by J. P. v a n d e r S t o k in his study of the observations on the same lightships.



The instruments to be used will be Carruthers's "vertical-log" (described in the Journ. du Conseil, Copenhagen, 1936). The authorities of the Rijkswaterstaat, who propose to start these observations on 1st January 1938, wanted a simple, rugged design which could be relied upon during heavy gales. Tests of sufficient duration, and comparison with "Ott" precision instruments, gave satisfactory results (see the accompanying figure). The pear-shaped weight at the lower end of the instrument is not shown in the original description, but should be added in order to obtain good results in strong currents. The revolutions of the "vertical-log" will be noted every half hour during the day and night on one counter only. The measurement of the current direction will be done with simple submerged floats, streamed at the end of a rope.

Yours very truly

J. van Veen.

van Speykstraat 50
's-Gravenhage 28th October 1937.

Reviews.

Bruno Schulz. "Allgemeine Meereskunde" in "Handbuch der geographischen Wissenschaft", edited by Fritz Klute. Lief. 153 u. 154, Allgem. Geograph., H. 8 u. 9, S. 227—286, Abb. 166—217, Taf. X—XII. Akademische Verlagsgesellschaft, Athenaion m. b. H. Wildpark—Potsdam, 1936.

The paper under review is a contribution to the section "Allgemeine Geographie" in the above-mentioned manual. The whole manual has been published in parts over the last eight years and is not yet quite finished. It consists of thirteen volumes, eleven covering "special geography" and two "general geography", comprising "physical geography" in one volume and "life on the earth" — the geography of plants, animals, and human beings — in another.

Contributors to "physical geography" are K. Kretschmer, Berlin; H. Lautensach, Greifswald; M. Hannemann, Frankfurt; W. Meinardus, Göttingen; B. Schulz, Hamburg; and F. Nussbaum, Bern. They deal with the history of geography as a science, the nature and methods of geographical science, the earth as a whole, general climatology, general oceanography, and the waters of the Continents.

B. Schulz points out in his contribution that oceanography of to-day is to be considered rather as part of geophysics than geography but that the connexion between oceanography and geography is still of great importance. The paper consists of three main sections dealing with: —

1) The space filled by the sea water
2) The principal qualities of sea water from a geographical point of view, and
3) The movements of sea water and their geographical significance.

The paper may be regarded as a general survey of oceanography in its present state from a geographical point of view. Some subjects of a more special nature are, however, also touched upon. This is the case in the discussion of the constituents of sea water, where, for instance, the compounds of nitrogen and of phosphorus, and the components of the carbonic acid system are dealt with. Further, such problems as the decomposition of the tide into its components, the bore phenomenon, the determination of the height of waves by the stereophotogrametric method, the deviation of the wind-driven current from the wind direction are mentioned and illustrated by pictures and diagrams.

The paper is a 60-page quarto edition, one-third of which is occupied by diagrams, tables, and pictures. The text is printed partly in ordinary type and partly in smaller type according to the character of the problem discussed.

For readers who want information on the various questions not mentioned, or mentioned in an abbreviated form only, references are given to manuals and publications on special topics of oceanography.

J. P. Jacobsen.

E. Goedecke. "Beiträge zur Hydrographie der südlichen Nordsee auf Grund der Beobachtungen der Winterfahrten des R.F.D. 'Poseidon' im Januar 1935 und Februar 1936." Arch. Deutschen Seewarte. Bd. 57, Nr. 1, S. 28, Taf. 13. Hamburg, 1936.

This treatise gives a very careful treatment of the hydrographic material collected during cruises on the "Poseidon" in the southern part of the North Sea and the German Bight, and supplemented by observations from liners and light-vessels and by those of a cruise of the "George Bligh" during January 1935 and February 1936.

The observations include temperatures recorded by thermograph, which afford a better opportunity to find the places where steep gradients indicate the limits between water masses of different origin.

The results are represented on 13 plates with, in all, 75 diagrams, giving isohalines, lines of equal density, and isotherms at the surface, and vertical sections along West-East, North-South, and cross directions. Isotherms at the surface are given for 11—13. January and 12—23. January 1936, isohalines for the entire period in January and February.

The difficulty of giving a really synoptic representation is indicated by the remarkable fact that in January the biggest difference between salinities at a repeat station was found after a time-lapse of only 1h.35min. ($1{\cdot}84^0/_{00}$).

It does not appear that the writer has tried to reduce the observations to a common epoch.

It is impossible to summarize the results of a detailed investigation like this, especially as little has been added to our knowledge of the main features. We knew long ago that, as a rule, the temperature and salinity of the North Sea water show little difference from the surface to the bottom, and that the distribution of temperature and salinity depends largely on the inflow of Atlantic water through Dover Straits, the inflow along the Scottish coast, and the mixing with water of lower salinity and more continental temperature on both sides. In the explanation of these phenomena, there is no reference to the influence of the tidal water in the wide mouths of the Schelde, which according to calculations by the reviewer*) can only explain the very high influence of the Dutch coastal water on the temperature distribution. On the other hand Dr. Goedecke has demonstrated very clearly the influence of wind and weather on the continent on the changes in the distribution in the North Sea, which caused the high salinity in the central part to reach a record value.

The variations from day to day in temperature and salinity are demonstrated by isopleths, showing very irregular motions.

The vertical sections show that in the eastern part the water of higher salinity penetrates under the surface water of lower salinity. At many other places, however, and even in the mouth of the Weser, the strong turbulence makes the isohalines practically vertical.

A number of cases in which long tongues of water of lower or higher salinity occur or closed isohalines are shown instead of tongues is explained by reference to the eddies which form along the borders of the intermixing currents. It would seem to the reviewer that sometimes these separate masses may be explained by transgression caused by periods of strong winds.

E. van Everdingen.

*) Med. en Verh. K.N.M. I, No. 102, No. 10, 1910.

E. R. Gunther. "A Report on Oceanographical Investigations in the Peru Coastal Current." Discovery Rep., Vol. 13, pp. 107—276, Plates XIV—XVI, 71 Fig. Cambridge, 1936.

"Variations in Behaviour of the Peru Coastal Current." Geograph. Journ., Vol. 88, No. 1, pp. 37—65, 6 Fig. London, 1936.

In the report on oceanographical investigations in the Peru Coastal Current which were undertaken by the R.R.S. "William Scoresby" in 1931, Gunther has dealt in great detail with the temperature and salinity of the waters and has discussed the phosphate distribution and certain features of the life of the sea. By making use of all available information concerning the character of the waters and currents off the coast of Peru he has been able to generalize a number of his important conclusions.

Gunther discusses the name of the current in considerable length and decides in favour of the name "The Peru Coastal Current", discarding the name "The Humboldt Current" which recently was revived by Wüst. Since the work of the "William Scoresby" was limited to the coastal region and since most sections run only to a distance of 100 to 200 miles out from the coast, the discussion has been limited to the coastal region. Within this region the distances between the stations which have been occupied are small, for which reason many sections show a number of interesting details which throw light on the processes of upwelling.

The upwelling has previously attracted great interest and it is natural that emphasis is placed on this phenomenon. Gunther's discussion reveals two interesting features. It is evident that the upwelling does not take place to the same extent in every region. Certain preferred areas exist between which tongues of warm water appear to approach the coast. The observations of the "William Scoresby" indicate the presence of two such tongues, one approaching Callao from the north-west and one approaching the Bight of Arica from the same direction. Temperature observations indicate that similar tongues are found in more southerly latitudes. Gunther interprets these tongues as showing the existence of anticyclonic swirls. He explains the appearance of *aguaje*, accompanied by disastrous destruction of fish and lesser forms of life by warm water, as the result of the convergence of the wedge of warm water with the coastal water.

The observations lead Gunther to the conclusion that the upwelling has an intermittent character. Under the influence of strong southerly winds the light surface water is transported away from the coast and replaced by cold water of higher salinity and high phosphate content, but when the wind dies off or reverses the cold and heavy water masses subside and lighter water spreads towards the coast. During the upwelling, water is drawn to the surface from depths not exceeding 300 metres and generally less than 150 metres. Below the upper layer water of high salinity and relatively high temperature appears to flow towards the south. Gunther is able to show a remarkably close correlation between the physico-chemical characteristics of the water and a number of biological phenomena.

Gunther's conclusions concerning the character of the complicated Peru Coastal Current are corroborated by reports from earlier expeditions and by incidental observations of southerly currents in the regions where Gunther supposes that the tongue of warm water approached the coast. Several such observations have previously been discarded as erroneous, but they fit remarkably well in the picture at which Gunther arrives. His system, showing intermittent upwelling followed by subsidence, and indicating quasi-stationary horizontal swirls of great dimensions, is in striking contrast

to the schematic picture which Defant recently has given of the region of upwelling off south-west Africa, but it is noteworthy that recent work off the coast of Southern California indicates conditions which are quite similar to those described by Gunther from the area off the coast of Chile.

When discussing the possibility of mixing leading to formation of water of greater density than both components and thus to sinking, Gunther appears to have made a mistake which has influenced his conclusion. On page 140 he states that if surface water from stations WS 617 and WS 615 were mixed in the ratio 5:8, the mixture would have a density of 25·94 and would not be in equilibrium with surrounding water until it had sunk to a depth of about 40 metres. The correct value of the density is, however, 25·52, and this water would be in equilibrium with surrounding water directly below the surface. This is a minor point since Gunther supposes only in one instance that processes of mixing may lead to sinking. On the whole he has undertaken a most careful discussion of the data and arrived at conclusions which, in the opinion of the reviewer, will find application within other areas.

H. U. S.

E. E. Watson. "Mixing and Residual Currents in Tidal Waters as Illustrated in the Bay of Fundy." Journ. Biol. Board Canada, Vol. II, No. 2, pp. 141—208, 26 Fig. Toronto, 1936.

The paper presents the hydrographic part of an investigation carried out by the International Passamaquoddy Fisheries Commission in order to determine the probable effect on the fisheries of a proposed tidal-power construction involving the damming of Passamaquoddy and Cobscook bays.

The Bay of Fundy is well known for its great tidal range. Another important hydrographic factor is the freshwater discharge. On an average 60% of this comes from the Saint John river. The yearly variations of the watershed have a considerable influence on the distribution of temperature and salinity in the bay.

Owing to the predominance of the tidal currents the residual currents are difficult to detect. The author discusses the different methods available for the determination of them and shows why no one has been able to give a satisfactory solution. After an introductory part, dealing with the topography of the bay, freshwater discharge, tidal effects and wind effects, the author gives a detailed analysis of the observations of temperature and salinity. The water movements in the different parts of the Bay of Fundy at different times of the year are considered. In Part III the hydrological phenomena, studied in connexion with the Bay of Fundy are discussed from a more general point of view, viz., estuarial mixing, the formation and maintenance of homogeneous water, the conditions for the occurrence of permanent residual currents and the effect of shoaling bottom on tidal waters.

It appears that the Saint John estuarial water flows out to sea as a strongly stratified layer, about 10 metres thick, retaining its lower boundary as far as Grand Manan island (74km.). This is due to the features of the river estuary and the adjoining sea. The turbulent influence of bottom friction in gradually shoaling waters is found to extend upwards to 20—50 metres. Stratified regions are found, where tidal mixing causes an outflow of mixed water at an intermediate depth with an inflow at both the surface and bottom, and regions where the fresh water is mixed

with salt water and flows away at the surface with a compensating inflow at the bottom only. The author makes an interesting attempt to calculate the local distribution of "mixing" which is defined as the work done against gravity when the interchange of different waters causes the density of the upper layers to be increased at the expense of the lower. The author's finding is that only a small part of the mixing in the Bay of Fundy which is effective in producing a circulation takes place at the head of the bay (14%), in the Quoddy passages (6%), and in the estuary of the Saint John river (3%).

The conclusions are based mainly on observations made in the year 1932. It would be of interest to compare the results with observations made during another year.

S. E. S.

A. E. Parr. "A Contribution to the Hydrography of the Caribbean and Cayman Seas." Bull. Bingham Oceanogr. Collect. Vol. V, Art. 4, pp. 1—110, 82 Fig. New Haven, Conn., 1937.

Nach der Bearbeitung der ozeanographischen Beobachtungen der "Mabel Taylor" im Golf von Mexiko von A. E. Parr in der gleichen Reihe (Vol. V, Art. 1, 1935) liegt mit dieser Veröffentlichung der Abschluss einer erstmaligen hydrographischen Untersuchung des ganzen amerikanischen Mittelmeeres vor. Parr stützt sich auf die Beobachtungen der "Atlantis" im Frühjahr 1933 und 1934, die durch die Zusammenarbeit vom Woods Hole Oceanographic Institution und Bingham Oceanographic Foundation gewonnen wurden. Temperaturen, Salzgehalte und die chemischen Faktoren auf den insgesamt 184 Stationen sind bereits in vollem Umfange im *Bulletin Hydrographique* 1934 und 1935 veröffentlicht.

Die Zweiteilung des Karibischen Meeres auf Grund der Morphologie, die Parr als Notwendigkeit betont, ist bereits gebräuchlich (O. Krümmel 1907) unter den Namen Karibisches und Yukatan-Becken.

Der hydrographische Aufbau der Schicht bis 1000m. wird in 18 Temperatur- und Salzgehaltsschnitten wiedergegeben. Der Temperaturaufbau der grösseren Tiefen wird dazu benutzt, die Satteltiefen der Durchlässe zu bestimmen. Dabei geht Parr von der unzutreffenden Annahme aus, dass die Tiefenlage des Minimums der Temperatur *in situ* der Satteltiefe des massgebenden Durchlasses entspricht. Er bestimmt für die tiefste Verbindung des Yukatan-Beckens mit dem Atlantischen Ozean 2530m., für die des Karibischen Beckens 2090m. Geht man von der potentiellen Bodentemperatur jedes Beckens aus, indem man die Tiefenlage des gleichen Wertes vor dem Durchlass als Satteltiefe ansieht und zieht man ausserdem die Sauerstoffverteilung heran, so ergeben sich für die Durchlässe beider Becken, Windward Passage für das Yukatan-Becken, Anegada Passage für das Karibische Becken, jedesmal 1600m. als Satteltiefe. Nirgends ist in den grossen Tiefen eine überadiabatische Temperaturschichtung festzustellen. Die verhältnismässig hohe Sättigung an Sauerstoff selbst im tiefen Cayman Graben spricht für eine gute Durchlüftung der Tiefsee.

Die horizontale Verteilung des Salzgehaltes wird für die Oberfläche, für den Horizont des Maximums und Minimums und bei der Temperatur von 15° gegeben. Diese Karten zieht Parr als Beispiele für seine Theorie heran (auch *Journal du Conseil*, Vol. XI, No. 3), nach der mit zunehmender vertikaler Schichtung die horizontale Turbulenz auf Kosten der vertikalen wächst. Es wird versucht, die schnelle Auflösung der horizontalen Unterschiede im Horizont des Salzgehaltsmaximums und -minimums im Karibischen

Meere von Osten nach Westen mit dieser Theorie zu erklären. Gegen die Beweiskraft der Beispiele ist einzuwenden, dass das Salzgehaltsminimum in keiner Dichtesprungschicht liegt. Wenig überzeugend ist die Erklärung des Eindringens des Salzgehaltsmaximums von NE. her, indem die Zentrifugalbeschleunigung des Sargassowirbels heranzogen wird. Das Wasser der Dichtesprungschicht, das das Salzgehaltsmaximum enthält, soll bei dem verminderten Reibungskoeffizienten dieses Horizontes besonders der Auswärtsbewegung aus der Sargasso-See unterliegen.

Einblick in das Bewegungsfeld vermitteln die dynamisch-topographischen Karten der 200, 600 und 1200d-bar Flächen. Die dynamische Bearbeitung wird einer späteren Veröffentlichung vorbehalten. Nach den Karten wird das Karibische Meer nicht gleichmässig von einer durchgehenden Bewegung erfüllt. Der Karibenstrom fliesst im südlichen Teil, ohne den SW.-Winkel zu erfassen. Hier wie südlich von Jamaika und südlich von Kuba bestehen grosse Wirbel, begünstigt durch die Morphologie. Die Verengung des Stromquerschnittes beginnt bei dem Auftreffen des Karibenstromes auf den Schelf von Honduras und erfährt eine weitere Verstärkung beim Übertritt des Stromes über die Jamaika-Schwelle. Das bedeutet, dass das ausgesprochen schmale Stromprofil des Yukatan- und Floridastromes nicht erst in der Yukatanstrasse gebildet wird.

Auf die $S = f(t)$-Kurven, die für sämtliche Stationen wiedergegeben sind, wird besonderer Nachdruck gelegt. Sie zeigen die laufende Erniedrigung des Salzgehaltsmaximums und die Erhöhung des Minimums von Osten nach Westen. Im übrigen ist das ganze Karibische Meer von einem verhältnismässig einheitlichen Wasserkörper erfüllt im Gegensatz zum Golf von Mexiko, in dem P a r r in der früheren Arbeit ein Nebeneinander von zwei verschiedenen Wasserarten in den obersten 200m. festgestellt hat.

Die verdienstvollen Arbeiten der "Atlantis" haben mit dieser Untersuchung eine weitere Darstellung gefunden. Die Entwicklung einer Reihe hypothetischer Vorstellungen von P a r r macht das Lesen der Arbeit reizvoll. Die kritische Stellungnahme zu einzelnen Fragen kann den Wert der Arbeit nicht herabsetzen.

G. Dietrich.

T. Gustafson und B. Kullenberg. "Untersuchungen von Trägheitsströmungen in der Ostsee." Svenska Hydrogr.-Biol. Komm. Skr. N. S., Hydrogr. XIII, 28 S., 8 Abb. Lund, 1936.

Bekanntlich verlangt die Theorie, dass ein ohne Reibung auf der Erdoberfläche frei beweglicher Massenpunkt, einmal angestossen, infolge der Erdumdrehung einen Kreis beschreibt innerhalb derjenigen Zeit, die ein Foucault'sches Pendel braucht, damit sich seine Schwingungsebene um 180° dreht ($= \frac{1}{2}$ "Pendeltag"): diese Periode hängt von der geographischen Breite ab und beträgt in der mittleren Ostsee ungefähr 14 Std. Nachdem bei schwedischen Strommessungen schon früher gelegentlich der Gedanke an den "Trägheitskreis" aufgetaucht war, haben die Verfasser, um die Frage zu klären, in den Jahren 1932/33 an 15 Stationen rund um Gotland wochenlange Beobachtungen mit dem Pettersson-Strommesser angestellt, die durch solche mit dem Ekman-Strommesser und mit dem Treibkreuz ergänzt wurden. In der Tat zeigt die harmonische Analyse mit aller Deutlichkeit das Vorhandensein einer 14—14½ stündigen Periode, die von der theoretischen nur um 10 Min. abweicht; die stärksten Drehströme betragen etwa 15cm./sec. Ein plötzlicher Windstoss brach die bisherigen Drehströme ab und liess neue mit anderer Phase entstehen. Allerdings sind die Stromfiguren, wie man

leicht nachrechnet, nicht kreisförmig, sondern elliptisch (Achsenverhältnis 1:2 bis 5:6), und die Phase ist örtlich verschieden, ohne dass sich jedoch ein Einfluss der Küste ergäbe. Die Trägheitsströme beschränken sich auf eine obere homogene Deckschicht, die bis etwa 20m. tief hinabreicht und durch einen schroffen Temperatursprung von den tieferen Schichten getrennt wird. Die Verfasser zeigen, dass der Dichtegradient in der Sprungschicht gross genug ist, um nach den Kriterien von G. I. Taylor und Goldstein die Turbulenz zu unterdrücken, sodass die Deckschicht sich als Ganzes tatsächlich fast reibungslos bewegen kann. In den tieferen Schichten dagegen wurden keine Drehströme gefunden; auch verzeichneten die Pegel an Land keine 14stündigen Schwankungen des Wasserstandes. Die Arbeit, die durch eine ausführliche Liste der Strommessungen ergänzt wird, stellt somit nicht nur eine theoretisch vermutete Tatsache fest, sondern wird auch bei der Planung und bei der Bearbeitung von Strommessungen zu beachten sein.

H. Thorade.

B. Kullenberg. "Interne Wellen im Kattegat." Svenska Hydrogr.-Biol. Komm. Skr. N. S., Hydrogr. XII, 17 S., 16 Abb. Göteborg, 1935.

Zum Beobachten der internen Wellen im Kattegat wurde ein schon früher von dem Verfasser beschriebenes Instrument benutzt, das in einem zum Schwimmen in Wasser von bestimmter Dichte ausgewogenen Fass mit selbstschreibendem Manometer besteht, und das an 8 Punkten zwischen Läsö und der schwedischen Küste Ende 1932 im ganzen 35 Tage ausgelegt war. Das Manometer verzeichnete sodann, wie tief sich Wasser von einer bestimmten Dichte unter der Oberfläche befand. Nach Ausscheiden unperiodischer Anteile erhält der Verf. deutliche interne Wellen der M_2- und der S_2-Tide (bis zu 69 und 59cm. Amplitude) und daneben eine vierteltägige, aber keine eintägige Gezeit. Die Welle wandert von der Küste nach SW. mit einer Geschwindigkeit, die der theoretisch berechneten gleich ist, und entspricht damit dem "shelf-experiment" Zeilons. Eine weitere Berechnung mit Hilfe des Schuster'schen Periodogramms ergibt noch eine Reihe anderer Perioden. Obwohl der gewöhnlich geforderte dreifache Wert der Expektanz nicht immer ereicht wird, hält der Verf. doch die Wellen dann für real, wenn sie in jeder Periode mit annähernd gleicher Phase wiederkehren. Eine mühsame Berechnung fördert so noch interne Schwingungen von 9·5, 11·0, 14·66, und 16·2 Stunden Perioden zu Tage, von denen die vorletzte etwa die Länge eines halben Pendeltages hat und möglicherweise als Trägheitswelle anzusehen ist. Die anderen würden als interne Seiches mit anscheinend sehr geringer Dämpfung aufzufassen sein.

H. Thorade.

M. Okada. "Estimation of the Steady Surface Current in Coastal Waters based on the Observation of Salinity and Soluble Silicate Content." Bull. Jap. Soc. Sci. Fish. Vol. III, No. 3, pp. 121—124, 2 Fig. Tokyo, 1934.
"A Graphical Method of Determining Ocean Currents." *Ibid.* Vol. III, No. 5, pp. 231—234, 2 Fig. Tokyo, 1935.

Beide Arbeiten versuchen, aus der Verteilung von Eigenschaften des Wassers auf neuen Wegen die Strömungen zu erschliessen, und zwar in solchen Fällen, in denen die dynamische Methode versagt, wie z.B. in seichten Küstengewässern.

(1) Das in der ersten Arbeit empfohlene Verfahren besteht in einer

Erweiterung des Knudsen'schen Satzes. Der Verfasser denkt sich im Meere ein dreiseitiges nicht zu grosses Prisma abgegrenzt, von der Oberfläche bis zu einer beliebigen Tiefe. Setzt man stationäre Verhältnisse voraus, so darf der Inhalt des Prismas an Wasser, Salz und Silikat sich nicht ändern; das ergibt drei Gleichungen. Nun seien Salz- und Silikatgehalt an den Seitenflächen und an der Grundfläche des Prismas bekannt, und ihre Änderungen an der Oberfläche durch Verdunstung und Niederschlag seien zu vernachlässigen. Dann enthalten die drei Gleichungen vier Unbekannte, nämlich den Durchfluss durch die drei Seitenflächen und durch die Grundfläche, und man kann das Verhältnis der vier berechnen. Der Verfasser wendet sein Verfahren an auf die Strömungen der Sagamibucht und findet gute Übereinstimmung mit Versuchen an einem Modell der Bucht, sowie mit den aus Temperaturbeobachtungen gefolgerten Auftriebsgebieten der Bucht selbst.

(2) Die zweite Arbeit will gewissen Missständen des in der ersten beschriebenen Verfahrens begegnen, denn dieses liefert einmal nur Verhältniszahlen für die Ströme, und sodann lässt es nicht erkennen, ob der Strom in der berechneten Richtung oder gerade umgekehrt setzt. Um auch hierüber eine Aussage zu machen, sind zusätzliche Annahmen nötig, unter denen die Vernachlässigung senkrechter Bewegungen hervorgehoben sei, sowie die Gleichsetzung der Austauschzahlen für Salz- und für Silikatgehalt. Der Verfasser zeichnet dann Linien gleichen Salz- und solche gleichen Silikatgehalts. Ist S der Salzgehalt, n die Richtung quer zu einer Isohaline, z die von der Oberfläche an gemessene Tiefe, so lässt sich zeigen, dass die Stromkomponente quer zu der Isohaline, v, proportional ist zu $(dS/dz):(dS/dn)$, dem Verhältnis des senkrechten Gradienten zum wagerechten, und diesen Quotienten konstruiert der Verfasser als Vektor. Hierbei sei bemerkt, dass man sorgfältig auf die Masseinheiten achten muss. Der Quotient schreibt sich übrigens noch einfacher, wenn man in Karte und Schnitt gleiche Stufen für dS verwendet; dann ist dn der Abstand zweier Isohalinen an der Oberfläche, dz derjenige derselben Isohalinen im Schnitt, und v wird proportional zu dn/dz. In gleicher Weise ergibt sich bis auf den gleichen Proportionalitätsfaktor die Stromkomponente quer zu den Linien gleichen Silikatgehalts. Damit hat man die Stromkomponenten in zwei verschiedenen Richtungen und durch einfache Zeichnung die wahre Stromrichtung. Die auf diesem Wege ermittelten Strömungen der Sagamibucht stimmen mit den nach dem ersten Verfahren gefundenen weitgehend überein. Für die Berechnung der absoluten Stromgeschwindigkeit benötigt der Verfasser noch die Austauschzahl, die er für Salz- und Silikatgehalt gleich der Austauschzahl für Wärme setzt, welch letztere er wiederum aus der Temperaturverteilung entnimmt. — Man möchte wünschen, dass die beiden Methoden einmal an einem grösseren Meeresgebiete ausprobiert würden; anstatt des Silikatgehalts könnte man dabei auch ein anderes Merkmal wählen, das vom Chlorgehalte unabhängig ist.

H. Thorade.

K. Kalle. "Nährstoff-Untersuchungen als hydrographisches Hilfsmittel zur Unterscheidung von Wasserkörpern." Ann. d. Hydr. usw., LXV. Jahrg., H. I, S. 1—18, Abb. 1—21, Taf. 3—9. Berlin, 1937.

Kalle sets out to show — and with considerable success — that nutrient salts may be used to supplement salinity and temperature for working out the past histories of water masses. He suggests for determination: turbidity, silicate, phosphate, total phosphorus, particulate (geformte) phosphorus, organic phosphorus, and nitrite.

Some will feel inclined to dismiss the proposal out of hand because nutrient salts are subject to change, not only by physical agency as are temperature and salinity, but also by biological processes of growth and decay. The author forestalls these objections by a critical examination of the conditions operative for each constituent. Wisely the winter months, January in 1935 and February in 1936, were chosen for cruises since then chemical conditions are most nearly static. The concordance between the conclusions based on the different constituents is remarkable. Nearly all agree on swirls in the north-western corner of the Southern Bight off the Norfolk Coast and in the German Bight and also on tongues of water off the mouths of the Thames, Rhine-Meuse, and Zuider Zee (Texel and Terschelling). Some of these, such as the north-western swirl of the Southern Bight, were previously unknown. Earlier failure to detect these may be due to either (a) inadequacy of salinity-temperature methods or (b) inapplicability of the method under discussion or (c) the possibly transient nature of swirls such as these.

In a shallow and partially landlocked area such as the southern North Sea variable eddies and swirls are likely to form quickly by the action of wind and as quickly to disappear. In the study of such temporary swirls the present method may prove of considerable value.

The several nutrients have not proved equally successful as accessories in the study of water movements. Nitrite and organic phosphorus were of least value. Nitrite is well recognized as amongst the most fugitive substances in the sea and its inclusion renders the paper less convincing. Total and particulate phosphorus were more successful than organic phosphorus, but the determination of all three of these involves long and difficult analyses which are not very suitable for routine purposes and would be well-nigh impossible on board ship. Phosphate, silicate, and turbidity were of greatest value. The determination of two of these is already included in many programmes and that of the third is a simple matter.

Winter conditions seem most appropriate for applying the nutrient-salt method to the study of water movement. In spring when nutrients are in rapid flux due to growth of plankton, interpretation of data would be much more difficult. In these two cruises 800—1000 analyses had to be made shortly after collection. However successful the proposed method may prove in practice, only the most energetic oceanographers are likely to welcome it with enthusiasm. Even so, a strong case has been made for further application of the method throughout the year.

L. H. N. C.

J. van Veen. "Onderzoekingen in de Hoofden." Uitgegeven vanwege het Ministerie van Waterstaat. S. 252, 148 Fig. s' Gravenhage, 1936.

This volume, in addition to giving the main results of the investigations carried out on the Rijkswaterstaat survey vessel "Oceaan" in 1934—35, contains both valuable and original contributions to the physiography of the coasts of Holland, those bordering the Straits of Dover and to the morphology of the sea floor itself. The fine series of diagrams, coloured charts and tables, together with the English and French summaries render the book of value to students who are not conversant with the Dutch language. The major contribution is to our knowledge of the tidal and other movements of the waters of the Straits, and here the author pays considerable attention to the useful work being done by Dr. Carruthers at the Fisheries Laboratory, Lowestoft. There is also a full bibliography.

Several popular misconceptions are cleared up; for instance, a 30% increase in the volume of water flowing in the Rotterdam distributary of the Rhine failed to check the entry of sea sand into the estuary. This sand is brought up by the return undercurrent of saline water and its deposition was, if anything, further accentuated by this increase in the volume of fresh water. The series of diagrams showing ebb and flood current velocities at different depths in the Straits show the usual parabolic form with certain local variations, the mean velocity in the vertical approximating to five—sixths of the surface velocity and occurring at 0·6 of the depth. Even though the bottom velocity is taken 0·15 metres above the sea floor it shows a considerable drop below the mean velocity, and this leads the author to issue a timely warning against the exaggeration of the effects of currents on sand movement because the height figure of such currents is rarely given. Sand grains ½mm. in diameter were found to start moving with currents of 0·3 to 0·5m./sec. at 0·15m. above the bottom and as these velocities are slightly lower than the maximum bottom streams of normal tides, some sand movement in the Straits is possible, but this was actually traced only on the sand banks and not on the major portion of sea floor, which consists of bare rock or stones. The purely oceanographical section concludes with a fine series of observations on current roses which are remarkable for their flatness. They tend to lie parallel to the neighbouring coasts and sandbanks.

The impression of stability of the materials on the sea floor given by the above observations is supported by the apparently static condition of the Varne Bank since 1848, but seems to be pressed too far when the author claims that the South Foreland and Cap Gris Nez have only receded 8—15 metres in the last 2,000 years. He considers that such sand banks as the Varne, Ridge and Falls are stable because they have taken on a streamline form, similar to the "Seif" dunes of the Lybian Desert. The Flemish Banks are more complicated and are assumed to be a composite mass of "flood paraboloid dunes" open to the WSW. and "ebb paraboloid dunes" open to the NE. This ingenious suggestion has much to commend itself, but the analogy with paraboloid wind-formed dunes is misleading as the latter appear to owe their form to vegetation holding back the horns whilst the main body of the dune advances in the centre, an action which clearly cannot apply to the sea floor. A welcome reference is made to the important but as yet little-explored subject of coastal curves.

The ancient dune system that existed partly on the site of, but mostly to the seaward of, the present Flemish shoreline in post-Roman times is considered to have been a normal offshore bar built on a prograding shore, whereas the modern dunes are wind-formed and are associated with a shore which is either retrogressive or stationary. These great changes from aggradation to erosion are not attributed to anything more than purely local changes near river mouths. In view of a somewhat similar sequence of events on the English coast at such places as Dungeness and Scolt Head, one might well question the local nature of the origin of these changes and look for something more widespread such as the fluctuations in sea level grouped as Flandrian by French writers. The author himself notes that the sea appears to be rising at the rate of 2½cm. in ten years on the Dutch coast and he refers to a similar movement in SE.England as indicated by the relevelling by the Ordnance Survey 1912—21. Though this interpretation has frequently been put upon the discrepancies between the results of these two Surveys it seems more probable that the divergence is really due

to a progressive error by the earlier surveyors of 1840—60, which increased in amount with distance from Liverpool.

Thus the volume as a whole contains much information useful to students in a wide field of interests and it has been produced by the publishers in a manner fully worthy of the very real contribution to the kindred sciences of Oceanography and Coastal Physiography which it clearly represents.

W. V. L.

J. A. Baak. "Regional Petrology of the Southern North Sea." pp. 128, 8 fig., 1 folder. H. Veenman & Zonen, Wageningen, 1936.

This book presents in a systematic form the results of and the deductions to be drawn from a heavy mineral analysis of bottom samples from the southern North Sea. The samples were provided by the survey vessel "Ocean" of the Rijkswaterstaat, the Borley collection of the English Marine Biological Association and the French survey ship "Pourquoi-Pas?" and also included sands from certain bores and sea beaches. Attention is paid to previous literature on the subject, particularly that of Edelman and Tesch, but the author is everywhere ready to add his own conclusions.

Bromoform separation and microscopical examination of 100 grains from each sample, counted along a pre-determined line in the slide, were found to give reliable results. One person could thus treat 40 samples a week and it is in such large-scale methods that lies the success of the work, for the author is emphatic that merely a qualitative analysis is of no value for comparative sedimentary petrology. The sediments were found to fall into five well-defined groups with certain rather important transitional areas. The minerals typical of each group arranged in decreasing order of importance are as follows: —

H Group. Garnet, Amphibole, Epidote, Saussurite.
A Group. Garnet, Epidote, Amphibole.
E Group. Garnet, Augite, Amphibole, Epidote.
North Hinder Group. Augite, Garnet, Saussurite, Amphibole, Epidote.
Tert. & Older Group. Zircon, Epidote, Rutile, Garnet, Amphibole.

The H and E groups occur near the coasts of Holland and England respectively and the A group lies further north. The clearly defined boundaries are taken to indicate that little movement of material has resulted from marine agencies. The A group represents glacial and fluvio-glacial Scandinavian material with re-worked Pliocene of Mindel age — the North Sea Glaciation of Solomon. Baak asserts that the sea was not then closed to the north and that there were merely a number of local ice-sheets, a statement that can hardly be accepted by English workers in view of the amount of Scandinavian material brought to our shores. The H group, consisting of a mixture of northern and Rhine materials is assumed to be of pre-Riss or Riss age. Its presence along the whole of the Channel coast of France is accounted for by the fact that the Riss ice blocked the North Sea entrance, and all its drainage with the accompaniment of outwash sands and gravels was forced into the Channel, thus initiating the Straits of Dover. This material has later drifted north-eastwards along the Belgian and Dutch coasts. The E group is derived from a westerly or north-westerly glaciation of Würm age and in order to account for the North Hinder group the Rhine is assumed to have turned south and flowed out through the Straits of Dover during the low sea-level of the Würm period.

The work thus represents a welcome and important addition to our knowledge of a technique and a subject which is only now beginning to receive the attention that is its due.

W. V. L.

E. Hentschel. "Allgemeine Biologie des Südatlantischen Ozeans." I. "Das Pelagial der obersten Wasserschicht." II. "Das Pelagial der unteren Wasserschichten." (="Das Pelagial der Tiefsee.") Wiss. Ergebn. deutsch. Atlant. Exped. "Meteor" 1925—1927. Bd. XI, S. 1—343, Abb. 123, Beil. 42. Berlin u. Leipzig, 1933 u. 1936.

Die "oberste Wasserschicht" (0—50m.) des Meeres allein besitzt "biologische Selbständigkeit." In ihr leben im Atlantik etwa 14×10^{22} Pflanzen und Tiere. Im Südatlantik lassen sich in quantitativer Hinsicht ein "zentrales Minimalgebiet", im Süden ein "grosses südliches Maximalgebiet" unterscheiden; von der "eutrophen" afrikanischen Küste gehen ferner die Kapzunge, die südwestafrikanische Zunge, die Kongo- und Kapverdenzunge als planktonreichere Gebiete gegen die Hochsee. Westlich von der Kapverdenzunge liegt das "Nördliche Minimalgebiet". Planktonärmer (oligotroph) ist auch die amerikanische Küste bis zum 30° S.B. und an der afrikanischen Küste das Guineagebiet. Die Erklärung für den verschiedenen Planktongehalt liegt in der Verteilung der Pflanzennährstoffe (Minimumstoffe), die aus der Tiefe emporsteigen und durch Strömungen sich weiter ausbreiten. Im Nannoplankton werden vier Hauptgruppen unterschieden: Diatomeen, Coccolithophoriden, Peridineen und Protozoen. Im Norden des Südatlantik herrschen Coccolithophoriden, im Süden Diatomeen vor. In der Protophytenverteilung kommt die Verteilungsweise des Gesamtplanktons deutlich zum Ausdruck, und dasselbe gilt von der Metazoenverteilung. Auf einen Metazoen kommen rund 1500 Protisten. Copepoden und Nauplien bilden 80% des Metazoenplanktons. Die "makroskopischen biologischen Erscheinungen der Meeresoberfläche" werden als Planktopleuston und makroskopisches Oberflächenplankton (Medusen, Gastropoden, Salpen, treibende Tange, Meerleuchten), Nektopleuston und Oberflächenpleuston (Säuger, Schildkröten, Fische) und Pteropleuston (Vögel) unterschieden. Eine besondere Besprechung erfährt das Pelagial an ausgezeichneten Stellen und an seinen Grenzen auf der Hochsee und an der Küste (Schelf, Buchten, Häfen, Flussmündungen) sowie im Bereich ozeanischer Inseln.

Das Leben der obersten Wasserschicht bestimmt auch das Pelagial der Tiefsee, das in seiner Verteilung daher der Planktondichte der obersten Wasserschichte ähnelt. Diese ist vorwiegend durch horizontal wirkende Kräfte bedingt, für die Verteilung des Tiefenplanktons dagegen sind vertikal wirkende Kräfte massgebend. Das Plankton nimmt anfangs bedeutend, später weniger stark nach der Tiefe zu ab, doch wiederholt sich noch in 2000m. die Verteilungsweise der Oberflächenschicht, wie die "Isostalaktenkarte" erkennen lässt. (Isostalakten sind Linien gleicher Intensität des in die Tiefsee absinkenden "Planktonregens".) Aber schon unterhalb von 200m. Tiefe ist die Planktonzusammensetzung wesentlich einfacher als in der obersten Wasserschicht. Die Tiefsee ist der "Herrschaftsbereich des heterotrophen Lebens" und dieses geht "nur zu einem Teil unmittelbar auf geformte Nahrung aus der autotrophen Sphäre zurück." In der Tiefsee überwiegen der Artenzahl nach Oberschichtenformen, der Individuenzahl nach aber Tiefseeformen. Nachdem bisher der Südatlantische Ozean als Ganzes Gegenstand der Untersuchung war, wird sodann die Planktonverteilung in seinen 11 "biologischen Hauptgebieten" dargestellt u.z. hebt Verf. hervor, dass es sich dabei "um ein Stück wirklicher Biogeographie

handelt. Soviele pflanzen- und tiergeographische Untersuchungen wir besitzen, so wenig eigentlich biogeographische, d.h. solche, in denen Pflanzen und Tiere eine völlig gleiche Berücksichtigung erfahren und bei denen das Hauptaugenmerk nicht auf einzelne Pflanzen und Tiere, sondern auf das Leben als Ganzes gerichtet ist." In den abschliessenden "allgemeinen Ergebnissen" wird zusammengefasst, was an Allgemeinerkenntnissen an der Hand des besonderen Beispieles, das untersucht worden ist, gewonnen werden kann. Hier wird nicht mehr nach dem Südatlantischen Ozean, sondern nach dem Ozean überhaupt gefragt. Während man bisher meist in "homocönotischer Betrachtungsweise" von der Untersuchung einzelner Planktonarten ausging, um zu klaren Ergebnissen zu kommen, weil nur sie homogen sind, kam Verf. zur Überzeugung, dass bei "holocönotischer Betrachtungsweise" das Gesamtplankton und seine Hauptgruppen, trotzdem sie heterogen sind, leichter verständlich seien als Gattungen und Arten. Für die Verteilung des Planktons werden als massgebend neben gewissen biologischen Faktoren angegeben: Licht, Strömungen, Pflanzennährstoffe, Wärme und Absinkstoffe, mit deren Hilfe sich eine Theorie der Verteilung des Planktons im Weltmeere aufstellen lässt. Jahreszeitliche Unterschiede in der Planktonverteilung sind in den wärmeren Teilen der Hochsee kaum und sicher nicht in der Tiefsee anzunehmen. Über den Zehrungsvorgang fehlen uns leider noch eingehendere Kenntnisse. Als Ortsveränderungen des Planktons werden unterschieden: 1. Zerstreuung, d.s. Ortsveränderungen von minimalen Ausmassen (so bei Zellteilungen der Protisten). Die bekannte Gleichmässigkeit der Verteilung des Nannoplanktons ist eine Folge der Turbulenz. 2. Verfrachtungen, d.s. Verschiebungen der Planktonmassen mit den Wassermassen oder gegen sie durch Winde (Physalien, Velellen). 3. Vertikalverschiebungen durch Absinken abgestorbener und lebender Organismen, stellenweise durch Konvektion. Als "grenzbedingte Erscheinungen" werden die Grenzerscheinungen an der Meeresoberfläche besonders beim Pleuston besprochen, sowie die Grenzbeziehungen zum Meeresboden (Verarmung), während in den Küstengrenzgebieten Wasseroberflächen- und Bodennähe zusammenwirken. Die Kennzeichen der Grenzen innerhalb der ozeanischen Wassermassen sind Unstetigkeit oder Mischung. In einem der Besprechung der "Biosphäre" gewidmeten Schlussabschnitt gibt Verf. in 3 schematischen Zeichnungen als "Grundergebnisse der Expedition" die Planktonverteilung in einem theoretischen Ozean und stellt damit "die Sonderuntersuchungen des Südatlantischen Ozeans in einen grossen wissenschaftlichen Zusammenhang"; seine Hauptabsicht aber war, "ein Ziel zu zeigen, das zu erstreben der Mühe wert ist."

Es ist leider unmöglich, in einem Referat über diese reich illustrierte Abhandlung, die so viel prinzipiell Neues bringt, mehr zu geben als einige Kostproben. Sie mögen zu gründlichem Studium der Schrift selbst anregen, und dieses wird gewiss auch in vielen Lesern den Wunsch aufkommen lassen, es möchten recht bald andere Teile des Weltmeeres (Ref. denkt zunächst an das Mittelmeer!) in gleicher Weise und ähnlich erfolgreich auf Profilfahrten erforscht werden.

Ad. Steuer.

N. I. Hendey. "The Plankton Diatoms of the Southern Seas." Discovery Rep. Vol. XVI, pp. 151—364, Fig. 3, Plates VI—XIII. Cambridge, 1937.

This report, which contains much that is new, is based mainly on the diatoms collected in the Southern Ocean, particularly in the neighbourhood of South Georgia, but various other parts have yielded useful material.

From a purely systematic point of view Mr. H e n d e y's work is valuable. He is a careful worker and knows his subject thoroughly. His classification discards the usual division into the Centricae and Pennatae, although for the main part based on that of S c h ü t t. The author has his own views of what constitutes a species and his so-called "phases" represent the closely related species, sub-species, varieties and forms usually recognized. The application of this system undoubtedly results in simplification, for in many cases several species are united, and the forms or phases are to some extent correlated with seasonal distribution. This is the case with *Corethron* which is here regarded as a genus consisting of only one species. All the others are "lumped" together as phases. The discussions relating to this species are important. The genus *Triceratium* has been specially studied. Although comparatively few were encountered in the present material its distribution is interesting and the new sub-divisions offered appear to be based on solid foundations. A really useful key to the genera is given (an extremely difficult thing to do in a satisfactory way), there is a clear and concise description of each species and several new species are established. If we miss a few of our old established names *(Actinoptychus undulatus* becomes *A. senarius*, and *Certataulina bergonii, C. pelagica)* we realize that the author is right according to the established rules of nomenclature and that he has retained several genera which are, strictly speaking, untenable, pending the verdict of the International Botanical Council.

With so much material it has been possible to study the wide variation present in most groups. The holoplanktonic flora of the cold water from the oceanic habitats forms the major part of the collections, and this consists of a small number of diskoid, and a larger proportion of filamentous pinnate forms. Environmental conditions apparently influence the form of the diatoms, those inhabiting warm water tending to be thin walled with a relatively large cubic capacity and a relatively low surface area, whilst those in the colder water have on the whole smaller and more vigorous frustules with heavier silicification.

M. V. L.

F. D. Ommanney. "*Rhincalanus gigas* (Brady), a Copepod of the Southern Macroplankton." Discovery Rep. Vol. XIII, pp. 277—384, 29 Fig. Cambridge, 1936.

This paper deals with the horizontal and vertical distribution and the life-cycle of *R. gigas*, the most dominant species of the macroplankton throughout wide areas of the Antarctic Sea. The investigation is based upon the very large material collected by "Discovery II" in the Falkland sector in the summer seasons 1931—32 and 1932—33 and throughout the cruise around the antarctic continent in the winter months of 1932. Our knowledge of the distribution and the life history of this special species is greatly increased through this investigation. So is also our general understanding of the life-cycle of the southern macroplankton organisms as a whole.

According to earlier investigations *R. gigas* occurs both absolutely and relatively in small numbers in the Weddell Sea waters where *Calanus acutus* (Giesbrecht) is the dominant copepod, while it is the dominant species in the waters flowing north-eastwards from the Bellinghausen Sea into the South Atlantic Ocean. This is strongly verified in this paper. The author has also found a remarkable and fine correlation between the distribution of

R. gigas and the temperature in the upper 100m. in these waters. During the summer months the species extended north of the Antarctic Convergence in the Falkland sector, but in the winter it was restricted to antarctic waters so that the convergence line formed the northern limit of the distribution.

As to the vertical distribution it was found that in the winter months the number of *R. gigas* became progressively reduced in the upper 250m., and in the Pacific Ocean it had after mid-winter practically disappeared from the upper water layers.

Comparison between the percentages of the total catch taken in the upper (100—0m.) and the lower (250—100m.) nets in the summer in the Falkland sector, and in April in the South Indian Ocean, strongly suggests that *R. gigas* undertakes seasonal vertical migrations. It spends the summer months in the upper water layers and in the autumn it descends to deeper layers. It appears again in the upper 250m. in the spring and in November it has returned to the layer between 100m. and the surface. Thus *R. gigas* spends the summer months in the north-eastward-flowing surface water, while the winter months are spent in the southward-flowing deep water masses.

R. gigas has a spawning period in the summer months (from mid-December and onwards) in the surface layer. The summer generation which originates from this spawning, descends in the autumn to deeper water layers where it has a spawning period in May-June. This latter spawning produces the over-wintering generation which is found in the water layers above 250m. in the following spring and which is spawning in the surface in the summer.

In the Falkland sector the summer spawning takes place in water of Bellinghausen Sea origin. It is not definitely proved whether or not there is any summer spawning in the Weddell Sea.

It is found that there is a certain relationship between the age-distribution of *R. gigas* and the temperature in the surface layer, and the author concludes that the summer spawning of *R. gigas* is related to the break up of the ice. The author thus finds that the spawning of *R. gigas* depends upon the same factors which have been found prevailing in the case of *Calanus acutus*. The author has arrived at this opinion independently and on a very comprehensive material. It seems that the optimum spawning temperature is higher in the case of *R. gigas* than in the case of *C. acutus*. The author has also found that the spawning of *R. gigas* takes place later in colder waters than in warmer. In colder waters the parent generation takes longer to attain maturity and fails to spawn until either the temperature of the water has been raised to a convenient degree by the seasonal southward movement of the isotherms or that the population has drifted into water of a suitable temperature for spawning.

Per Ottestad.

P. Jespersen. "On the Size of *Calanus hyperboreus* Krøyer in West Greenland Waters." Int. Rev. d. ges. Hydrobiol. u. Hydrogr. Bd. 34, H. 1/2, S. 102—107, Fig. 3. Leipzig, 1937.

Dr. Jespersen deals with the size of *Calanus hyperboreus* in relation to water temperature, and shows us that the length of these calanoids decreases somewhat when areas containing an admixture of warmer water are sampled. A similar but much greater variation has been noted in the same area for the closely allied species *Calanus finmarchicus*, the size of which may vary

very markedly. In spite of the fact that the variations in size observed by Dr. Jespersen are small in the case of *C. hyperboreus*, he makes the correlation clear enough, and adds thereby another fact to our very slender knowledge of the regulation of size in such forms by hydrographic conditions. This problem, which seems at first sight to be of indirect importance, should, in my opinion, receive more attention than is at present generally devoted to it.

Although it is probable that temperature is the main factor governing these variations in size, we must not jump to the conclusion that such is always the case. I have, for example, found that with *Calanus finmarchicus* in the North Sea, the smallest females occur in February and March, and the largest in May, when the average temperature is considerably higher than in the former months. Although this appears to be directly opposed to the findings of Dr. Jespersen, such is not really the case, for we have evidence that with North Sea *Calanus* in early spring, the scarcity of food before the diatom flowering is a very important factor, and not only is this so, but we have reason to believe that the *Calanus* of May in this area are of different origin to those found in February. The discrepancy between these observations and those of Dr. Jespersen in an entirely different area is thus without significance.

There is one point concerning the measurement charts shown on p. 106 (Fig. 3) in Dr. Jespersen's paper to which he makes no reference and which is interesting. It is the great similarity of the two curves from the two different areas. In each there are four main peaks; those on the upper side of the modal point correspond remarkably well, and it seems as if each group contains four sub-groups — possibly different generations.

The establishment of a size-temperature relation in a copepod species, or indeed for that matter in any species, should be of value as an indicator of water movements, and if sufficiently developed could be of great use in hydrobiological research generally. I therefore feel that Dr. Jespersen's paper is important, and I am certain that those workers who can find time and opportunity to study material as he has done will be well rewarded for their labours.

S. G. Gibbons.

R. S. Wimpenny and E. Titterington. "The Tow-Net Plankton of Lake Qarun, Egypt. December 1930 to December 1931." Min. of Comm. and Industr., Egypt, Fish. Res. Direct. Notes and Mem. No. 14, pp. 57, Fig. 13. Cairo, 1936.

This interesting work is chiefly concerned with the study of the annual quantitative modifications of zooplankton and variations of the "fat" content in different hauls, with special reference to changes in the ratio of Na, K, and Mg to Ca. The authors also take into consideration the Nile waters supplying Lake Qarun.

These matters occupy the first part of the work. The second deals with the different stages of development of *Leander squilla* var. *elegans*. There is an appendix showing the working out of the values of χ^2 from the *Diaptomus* length measurements.

The work was divided, Wimpenny undertaking the biological, statistical, and general parts, and Titterington the chemical part.

The authors concentrated their attention on the three most important species: *Diaptomus salinus* Daday, *Leander squilla* var. *elegans* Rathke, and

Moina salinarum Gurney. Such a method is very efficient, especially in quantitative investigations. There are two types of annual distribution of these species, as follows: "A cold period was characterised by a simple community abundant in individuals. A warm period followed with a more complex community and fewer individuals." The mass of plankton in the period from March to June was several times greater than in the second half-year.

The quantity of *Diaptomus* and *Leander* reached its maximum in the cold period (12·7°—20°C.), whereas the maximum abundance for *Moina*, which is a warm-water species, was recorded on 30/VI and 17/X/1931 (19·9°—25°C.).

There are two broods of *Diaptomus*. The first takes from 2½ to 3½ months to reach the adult stage in mid-March, the second becomes adult in mid-April after 1 to 1½ months. The second and more important brood amounted on 16th April 1931 to 1,720,000 individuals in one haul with the maximal annual volume of plankton of 495 c.c. The rapid development of the second brood is due to a higher water temperature (4° more than in the development of the first brood).

The authors record two size-groups of *Diaptomus*, a "large group" (first brood) and a "small group" (second brood).

Leander also has two broods but at different times, the first in May and the second from August to September. Measurements of *Leander* showed that in all stages there were large individuals in April in "cold" water, and small individuals in the warm water of September and October. So there is a general reduction in size connected with the warm water period. The article gives many interesting new data on this subject. The authors explain this phenomenon as follows: "that in the warm period there is a shortage of algal food and an increased rate of respiration ...." and "that as the temperature rises the viscosity will decrease."

The factor next in importance is the decrease of dissolved oxygen from 104% to 64·8% saturation, which occurs between the beginning and the middle of the warm period, whereas all the vital processes become more intensive with an increase of temperature. We have, however, as yet no theory with a general bearing on all aspects of these phenomena.

The biology of the young stages has a great importance in modern planktology, as they form the bulk of living matter in the plankton.

The detailed morphological description of 7 stages of *Leander* is a very valuable contribution to the general knowledge of development of organisms.

The authors also make a comparison of the sizes of eggs and different stages of *Leander* with some other shrimps from different regions, showing that the greater size is connected with colder, or brackish water. Therefore the Egyptian *Leander* will have the smallest size at all stages.

The chemical data are also of great interest. For instance, the fat content of the samples was higher when "the Ca content was lowest and when Ca was relatively least important, compared with Na, K, and Mg."

The authors give in their papers much interesting and valuable information with a detailed interpretation, and we can only regret that they estimate the mass of plankton in numbers of organisms instead of by weight, which would better show the role of those species in the biomass of the plankton samples. From this point of view *Leander* would have a greater importance in the biomass of plankton in Lake Qarun.

B. G. Bogorov.

H. I. Battle, A. G. Huntsman, A. M. Jeffers, G. W. Jeffers, W. H. Johnson and N. A. McNairn. "Fatness, Digestion and Food of Passamaquoddy Young Herring." Journ. Biol. Board Canada. Vol. 2, No. 4, pp. 401—429, 6 Fig. Toronto, 1936.

The Passamaquoddy region of southern New Brunswick is one in which there is an exceptionally great concentration of herring, especially of immature fish, which are of suitable size for canning as sardines. The present report gives a survey of various investigations on the food-biology of these herring which in different localities of the region and often only a few miles distant from each other show more or less constant differences. This is especially the case with the fatness of the herring. For the study of fatness the herring were measured and weighed, and the degree of fatness was determined by calculating the commonly used condition factor, which is $\frac{100 \times W}{L^3}$, where W = weight in grammes, and L = total length of fish in centimetres. In localities related to the main Quoddy passage the herring are found to be fattest and here they contain the most food, the most important food organisms for the intermediate and larger sizes of herring being *Calanus* and *Meganyctiphanes*. These organisms are those most regularly found in greatest abundance in the passage.

Concerning the feeding the report contains several interesting facts. The food is taken by an act of capture and the herring are unable to feed in darkness, but feed more rapidly with increased illumination at intensities not far from that of moonlight, and in some localities the fish contain the most food and appear to have fed most selectively after moonlight nights. A correlation seems to exist between the fatness of the herring and the amount of food present near the surface, at least during the summer season.

Several questions concerning the digestion of the food have been studied experimentally in tanks, in which there was control of both temperature and feeding. The time involved in digestion varies with temperature, a full stomach being cleared in 6 to 7 hours at 20°C. and only after 25½ hours at 6° (length of herring 14—16cm.), but the rate of digestion seems, on the other hand, also to depend to a certain degree on the size of the fish. At 14° small herring (length 9—12cm.) seem to require about 14 hours for clearing, whereas larger fish (14—16cm.) only require about 10½ hours.

The present paper, which is to be regarded as a preliminary report, contains a number of details which are of the greatest interest to everyone interested in the food-biology of the herring, and it is to be hoped that the investigations will be continued.

P. Jespersen.

H. Wood. "Race Investigation of the Herring Population of Scottish Waters." Fisheries, Scotland, Sci. Invest., 1936, No. III; pp. 1—52, 5 Fig., 1 Chart. Edinburgh, 1936.

Wie in den meisten Heringsfanggebieten, so sind auch in der nordwestlichen Nordsee die Heringsschwärme nicht einheitlich in ihrer Zusammensetzung, sondern es sind verschiedene Komponenten vorhanden, die verschiedenen "Biologischen Gruppen" angehören. Die Frage nach der Charakterisierung dieser Gruppen, nach der Abhängigkeit der Schwankungen in der Zusammensetzung der Schwärme und alle damit zusammenhängenden

weiteren Fragen sind seit langer Zeit Gegenstand der Untersuchungen. In Bezug auf die "Rassen"-Frage sind die Ansichten jedoch immer noch stark geteilt. Die schottischen Untersuchungen fussen, wie auch die deutschen, immer noch auf der von Heincke entwickelten Methode, allerdings gewissermassen in einer abgekürzten Form. In der vorliegenden Arbeit von Wood sind neben der Wirbelzahl auch die Kielschuppen (K_2) berücksichtigt. Diese sind in der letzten Zeit wegen ihrer Variabilität bei den Untersuchungen sehr vernachlässigt worden. Wood ist der Ansicht, dass aber gerade diese Variabilität für die Untersuchungen gewisse Vorteile hat.

Das untersuchte umfangreiche Material wurde während der ganzen Dauer der schottischen Heringsfischerei gesammelt und stammt von den Fangplätzen vor den Küsten Shetlands und vor den Ost- und Nordküsten Schottlands während des Sommers und Winters und aus den Mündungsgebieten des Forth und Clyde während des Winters und Frühjahrs.

Der Verfasser streift kurz die Frage der "Rasse", worüber bekanntlich die Ansichten geteilt sind. Als Aufgabe der vorliegenden Untersuchungen nun wird es bezeichnet, in den Verschiedenheiten der körperlichen Merkmale ein Mittel zu finden, die einzelnen "Gemeinschaften" in jeder Fangzeit voneinander zu unterscheiden und ihre Wanderungen festzustellen. Das Wort "Rasse" wird hier benutzt, weil es als der passendste Ausdruck angesehen wird, um eine geschlossene Laichgemeinschaft zu bezeichnen. Damit schliesst sich die schottische Auffassung ganz der deutschen Auffassung in dieser Frage an.

Es werden zwei Gruppen von Heringen für die schottischen Gewässer unterschieden, die als schottische Frühjahrsheringe und schottische Herbstheringe bezeichnet werden. Die erste Gruppe laicht im Februar und März, die zweite im August und September. Es ist nun eine Hauptaufgabe dieser Untersuchungen, die Rassenmerkmale dieser beiden Gruppen zu bestimmen. Zunächst wird noch etwas über einige Abweichungen im Verhalten und in der Verbreitung dieser beiden Rassen gesagt, wobei es sich zur Hauptsache um die verschiedenen Laichplätze und Laichzeiten handelt. Die Frühjahrslaicher stehen unter stärkerem atlantischen Einfluss, während die Herbstlaicher ausgesprochene Nordsee-Heringe sind.

In den folgenden Abschnitten werden nun die Untersuchungen im einzelnen besprochen. Es ist zu begrüssen, dass nicht allein die Mittelwerte für die Charakterisierung der körperlichen Merkmale herangezogen werden, sondern auch die Variationsbilder. Dadurch wird eine wesentlich grössere Klarheit gewonnen. Es kann hier nicht auf nähere Einzelheiten eingegangen werden, es mag hier nur noch auf die Heranziehung des Merkmals K_2 hingewiesen werden. Es sind gewisse Bedenken betreffs dieses Merkmals berechtigt, und diese Bedenken werden von Wood auch durchaus gewürdigt. Aber trotzdem scheint es doch angebracht zu sein, dieses Merkmal nicht ganz zu vernachlässigen, sondern es zur feineren Unterscheidung, gewissermassen als Kontrolle, mit heranzuziehen.

Besonders schwierig ist die Untersuchung unreifer Heringe, die man also nicht vorher nach Reifestadien trennen kann. Will man auch die Zusammensetzung solcher Schwärme feststellen können, ist es eben notwendig, zunächst einwandfrei die Merkmale der einzelnen Rassen festzulegen. Dann wird man auch die Zusammensetzung der Schwärme jugendlicher Heringe analysieren können.. Auf diese Weise stellte Wood fest, dass im Gebiet zwischen Viking-Bank und dem "Patch" (westl. Utsire) im Frühjahr, auf den Shetland-Gründen im Sommer und auf dem Fladengrund im Herbst die unreifen Heringe zur Hauptsache Frühjahrslaicher sind.

Die schottischen Herbst- und Frühjahrslaicher sind leicht durch die wesentlich voneinander abweichenden Wirbel- und K_2-Werte zu unterscheiden. Hierbei handelt es sich um zwei verschiedene Rassen, bei denen eine geschlechtliche Mischung unmöglich ist. Bei beiden Rassen werden aber von Wood noch einige Untergruppen unterschieden. Es wird weiter festgestellt, dass in den Gebieten vor der NO.-Küste Schottlands im Juni und Juli und auf dem Fladengrund von Ende Juli bis etwa Mitte September ein Hering mit höherer K_2-Zahl vorkommt, als sie der schottische Herbsthering aufweist. Das deutet auf den reifenden Hering der mittleren und südlichen Nordsee hin. In seiner Wirbelzahl stimmt dieser Hering mit dem schottischen Herbsthering überein, er unterscheidet sich aber von ihm durch eine höhere K_2-Zahl.

Wood zieht nun aus seinen Untersuchungen die Schlussfolgerung, dass die Heringsschwärme, auf denen die schottische Fischerei in der nordwestlichen Nordsee während des Sommers und Herbstes beruht, aus drei verschiedenen Bestandteilen bestehen, welche in ihren Mengenanteilen zeitlichen und örtlichen Schwankungen unterworfen sind. Die Schwärme unreifer Heringe zeigen nur eine geringe Durchmischung. Es handelt sich hierbei fast ausschliesslich um Frühjahrsheringe.

Die vorliegenden Untersuchungen von Wood bilden einen ausserordentlich wertvollen Beitrag für die Heringsuntersuchungen und verdienen deshalb grösste Beachtung. Man darf hoffen, dass man in der nördlichen Nordsee allmählich immer mehr Klarheit über die dortigen Verhältnisse gewinnt.

Schnakenbeck.

A. R. Molander. "Neue Untersuchungen über die Flunder in der Ostsee." Svenska Hydrogr.-Biol. Komm. Skr. N.S. Biol., Bd. II, Nr. 1, S. 1—8, Fig. 6. Stockholm, 1937.

Die Arbeit stellt einen neuen Bericht über die fortlaufende Überwachung der schwedischen Flunderfischerei von Schonen und Blekingen und die Flunderbevölkerung im Ostseegebiet vor den genannten Küsten dar. Wir erhalten das bezeichnende Bild eines Bestandes in fortschreitender Befischung. Von dem alten angehäuften Bestand sind keine wesentlichen Reste mehr vorhanden, die Fischerei stützt sich auf den laufenden Bestand und ihr Ertrag weist daher unter dem Einfluss der Fluktuationen ausgesprochene Schwankungen auf. Der Nachwuchs an Flundern ist durch die Bodenbeschaffenheit im Gebiet dicht an der Küste und durch das geltende Mindestmass verhältnismässig gut geschützt. Doch ist die Befischung immerhin so stark, dass langsame Veränderungen im Bestande vor sich gehen: Die Wachstumsgeschwindigkeit nimmt zu. Das zeigt sich in der Durchschnittslänge der Altersgruppen sowie darin, dass in den letzten Jahren eine jüngere Altersgruppe (III) einen wesentlichen Anteil an den gelandeten marktfähigen Flundern gewinnt. Der Anteil der Männchen an den älteren Gruppen geht zurück, was mit dem schnelleren Wachstum und dem früheren Eintritt der Geschlechtsreife in Beziehung stehen dürfte. Die wissenschaftlichen Fänge des "Skagerak" lassen die starke Lichtung der Flunderbevölkerung während der Abfischung des angehäuften Bestandes 1923—1930 deutlich erkennen, für die letzten Jahre ist eine solche dagegen nicht nachzuweisen. Der Ertrag der Fischerei hat sich bei der Blekingen-Fischerei bei starken Schwankungen nicht vermindert. Allerdings sind die in verhältnismässig tiefem Wasser gelegenen Fangplätze in den letzten Jahren etwas östlich verlegt worden. Die Schonenfischerei, die auf flacheren Gründen stattfindet, lässt dagegen

eine gewisse Abnahme der Erträge deutlich erkennen. Allerdings steht noch nicht fest, ob dies auf die Lichtung des Bestandes oder auf die Wirkung der Fluktuationen zurückzuführen ist. Die festgestellten Veränderungen in der Wachstumsgeschwindigkeit und der Alterszusammensetzung der Fänge sprechen sehr für die erste Erklärung.

An einer ganzen Reihe von Beispielen des Plattfischfanges im Bereich der Übergangsarea und der Ostsee haben wir feststellen müssen, dass die Entwicklung, die hier bei der Flunderbevölkerung vor der schwedischen Ostseeküste offenbar begonnen hat, fortschreitend zu ganz unwirtschaftlichen Fischereibedingungen führt. Energische vorbeugende Massnahmen sind in einem solchen Falle daher ohne allen Zweifel geboten. Verf. weist nach, dass die Einführung einer Schonzeit während der Laichperiode die schwedische Fischerei zu schwer treffen würde, dass aber auch die Erhöhung des Mindestmasses während der Laichzeit eine wirksame Schonmassnahme sein würde.

Ref. teilt die Anschauung, dass die Schonung der kleinen Nutzfische in erster Linie sicher gestellt werden sollte. Doch glaubt er, dass man darüberhinaus die allgemeinere Frage der optimalen Befischungsstärke in den meist befischten Meeren sobald als möglich wird klären müssen.

A. B.

H. O. Bull. "Studies on Conditioned Responses in Fishes. Pt. VII. Temperature Perception in Teleosts." Journ. Mar. Biol. Assoc., N.S., Vol. XXI, No. 1, pp. 1—27, 3 Fig. Plymouth, 1936.

Continuing the studies formerly reviewed in this Journal Mr. Bull now studies the discrimination of temperature by fishes by means of the training method. Fishes had to splash their way upstream to the head of a tank partially filled with water in order to get food, as soon as heated water flowed down the tank. The differences in temperature were recorded by means of a galvanometer system; the fishes themselves were observed through a periscope. First the animals were trained to a relatively high increase of temperature (0·4—3·0°C.), and after this training had been successful the rise of temperature was gradually lowered to the lowest practicable limit (0·03—0·1°C.). Nineteen species of teleosts were used in these experiments, of one of which *(Gadus callarias)* a detailed record is given, while shorter summaries indicate the principal results of the others. The number of associations required for producing a reaction to the increase of temperature varied from 11 *(Pleuronectes platessa)* to 56 *(Nerophis lumbriciformis)*, while the minimum increase of temperature reacted to varied from 0·03 to 0·07°C. In the discussion of his results the author argues the importance of these findings for the behaviour of fishes in their natural habitat.

J. A. Bierens de Haan.

G. M. Spooner. "The Learning of Detours by Wrasse *(Ctenolabrus rupestris* L.)." Journ. Mar. Biol. Assoc. N.S., Vol. XXI, No. 2, pp. 497—570, 13 Fig. Plymouth, 1937.

Following up the work of Dr. Russell (1931) on detours with sticklebacks the author in this paper reports the results of extensive experiments of the learning of detours by the Rock Wrasse *(Ctenolabrus rupestris)*. For this purpose the fishes were kept isolated in rectangular glass dishes and first accustomed to take their food off a piece of thin wire.

Before each experiment an obstruction necessitating the making of a detour to the food was carefully lowered into the tank. The time the fish used to reach the food around this obstruction was noted and taken as a measure of its learning. One fish was trained in this way to the easier task of entering a glass tube covered by heavy black meshwork and fixed horizontally on a support, in which the food was suspended at a distance of 8·5cm. from the opening, while 10 other fishes had to learn to make a detour of 6·5cm. round a vertical plate of plain glass, which was sometimes edged with a black strip or marked with a meshwork of scratched lines. Detailed descriptions are given of all the experiments, supplemented by learning curves. It is of course not possible to report the details of these experiments in a few lines. It may suffice to say that all animals more or less learned to make the detour in a smaller or greater number of experiments, the time required for it falling from several minutes at the start to a few seconds at the end. Sudden improvements in the performances appeared in several of the animals. One fish curiously enough did not learn the shorter but a longer way (around the apparatus) to the food. That plain glass proved to make a more difficult detour than the squared glass does not surprise us so much as it seems to have done the author, as it is quite possible that the plain glass is scarcely visible to the fish.

In the second part of the paper the author gives a theoretical discussion of the problem of learning in fish. Here Thorndike's physiological theory of learning is rejected, as are the connexionist and associationist hypotheses, the latter because the author observed no backward learning in his animals. Because of the effects of visual changes in the surroundings on the performance of the animals (meshwork on the glass plates made the detours easier, as we have already seen) the author believes the improvement in the performance to be due to changes in "sensory organization." It is not quite clear if the author wishes these words to be taken in a physiological or in a psychological sense, but as he prefers to speak of "afferent" rather then of "sensory" processes, and speaks of "affector processes" and of "processes of neuro-synthesis" I believe that the former is the case. Anyhow I believe that more is required for the learning of a detour than a simple neurophysiological process and that only by working up acquired experience the animal may arrive at what the author rightly calls "the prehending of some general relations in the external situation," that will enable it to make a detour to reach its goal.

J. A. Bierens de Haan.

C. F. Hickling and E. Rutenberg. "The Ovary as an Indicator of the Spawning Period in Fishes." Journ. Mar. Biol. Assoc., N.S., Vol. XXI, No. 1, pp. 311—318, 1 Fig. Plymouth, 1936.

Recent accounts of the development of the eggs of fishes have led to the general conclusion that there is a main ovarian egg-stock, from which a quota ripens for spawning each year, and to which each year a quota of new eggs is added, the minimum intra-ovarian period being two seasons.

Hickling and Rutenberg, in this short but most interesting paper, deal with the hypothesis that measurements of the diameters of eggs in well-advanced ovaries may give evidence of the duration of spawning; where the spawning period is short the quota of maturing eggs being withdrawn from the main egg-stock in a sharply distinguishable group; and where long and indefinite, without sharp separation between maturing quota and main egg-stock.

They test the hypothesis with species of known spawning habits, comparing southern North Sea herring with pilchard, and North Shields haddock with hake. The spawning periods of both pilchard and hake are known to be long, while those of the herring and haddock are more restricted. It was duly found that in the two former there was no sharp separation between the ripening quota and the main egg-stock, while, in the two latter, clearly defined groups were present.

The suggestion that such measurements of intra-ovarian eggs may be used to provide information regarding species the spawning habits of which are unknown should now be in general acceptance. The writers cite several investigators who have used similar methods, although they have omitted perhaps one of the more extensive of recent works upon the subject, "Maturity of the California Sardine *(Sardina caerulea)* determined by Ova Diameter Measurements", by F. N. Clark (Div. Fish and Game, Calif., Fish. Bull. No. 42, Sacramento, 1934).

The paper concludes with an important rider to the effect that the use of Hjort's scale of maturity stages encounters difficulties when applied to a fish of prolonged spawning period, for as the eggs contained in the ovary are progressively ripened and shed, the ovary itself grows smaller and to the naked eye appears to reverse the stages by which it attained its full maturity.

D. S. R.

E. Lea and A. E. Went. "Plastic Copies of Microscopical Reliefs, especially of Fish Scales." Hvalrådets Skr. Nr. 13, pp. 18, 6 Plates. Oslo, 1936.

The authors restate the considerations favouring the senior author's suggestion that multiple replicas of fish scales be provided for exchange among investigators in several countries. (Lea, Einar. "The Herring's Scale as a Certificate of Origin." Rapp. et Proc.-Verb. LIV, 1929).

The technical procedure for preparation of such replicas is as follows: Cleaned scales which have neither been allowed to dry nor subjected to the action of coagulating preservatives (storage in alcohol is permissible if dehydration is accomplished by a graded series of alcohols) are glued, sclerotic side uppermost, to very carefully cleaned glass plates with glycerine jelly. The spiny portions of ctenoid scales are coated with glycerine jelly individually. When thoroughly dry the exposed surfaces of the scales are rubbed with a solution of castor oil in acetone to prevent sticking in subsequent processes. The surfaces of the glass plates bearing the scales are carefully brought in contact with sheets of celluloid the surfaces of which have been thoroughly softened with a mixture of acetone and amyl acetate. Care must be taken to avoid entrapping air bubbles. After the softened celluloid has set under moderate pressure for a time, it is carefully stripped off and the sheets are attached at their margins to wooden blocks. When thoroughly dry, an indefinite number of exact positive replicas may be cast from the moulds formed in the celluloid plates, by flooding the latter with warmed glycerine jelly which is hardened with formalin, allowed to dry, and then stripped off the plate.

The very fine illustrations demonstrate the marked superiority of the replicas to the scales themselves.

The reviewer has experimented sufficiently along similar lines to be convinced that no substantial simplification of the rather elaborate process is possible if the original scales are to be preserved unaltered, and if exact

and uniform positive replicas are required. Negative moulds can be prepared more quickly and more conveniently by methods requiring sufficient pressure to force the scales into unsoftened or slightly softened celluloid, or into soft metals, but only at the cost of slight stretching of the original scales. Also, if the additional step of casting positives be omitted and a series of negative impressions of a single scale be prepared for exchange by pressure methods, uniformity must be sacrificed, for there is a progressive stretching of the original scale when repeated impressions are made. (With cod scales the total diameter of the twentieth impression exceeds that of the first by about 1·5 per cent.) Consequently, the method described is to be recommended in preference to pressure methods in those cases in which preservation of the original scales or maintenance of exact uniformity in the product is of greater importance than the saving of time and labour.

R. A. Nesbit.

H.B.Moore. "The Biology of *Littorina littorea.* Part I. Growth of the Shell and Tissues, Spawning, Length of Life and Mortality." Journ. Mar. Biol. Assoc., N.S., Vol. XXI, No. 2, pp. 721—742, 10 Fig., 1 Plate. Plymouth, 1937.

The material used by Dr. Moore in his investigations into the biology of *Littorina littorea* was collected from three localities near Plymouth in which the conditions differed considerably. The specimens were collected by hand-picking, and, in the case of the representative samples, by sieving a surface sample of ground from an area of known size. The samples were collected at approximately monthly intervals. The methods employed in examining the material thus collected are described in detail in the paper. The rate of shell growth in the first and second years is described for each area, and the results are shown in a series of graphs. The size-distribution figures being useful only up to an age of about two years, after which the successive peaks overlap too much to be distinguished, for finding the growth-rate of the larger sizes marked individuals were employed. In a number of periwinkles, the sex of which had been determined, it was found that growth proceeded faster in the females than in the males. No ripe females were found on the grounds before early February, but spawning proceeded rapidly from then until mid-March, although some females were not yet completely spent at the end of May. The age at first maturity, and at the first considerable spawning, is given for each of the three localities examined. The mortality rate is discussed in some detail. The paper, which contains a number of explanatory diagrams, is a valuable contribution to our knowledge of the biology of *Littorina littorea.*

F. S. W.

G. I. Crawford. "A Review of the Amphipod Genus *Corophium,* with Notes on the British Species." Journ. Mar. Biol. Assoc., N.S., Vol. XXI, No. 2, pp. 589—630, 4 Fig. Plymouth, 1937.

Die vorliegende Arbeit enthält ein Verzeichnis aller bis jetzt bekannten Arten der Amphipoden-Gattung *Corophium* Latreille, 1806, im ganzen 32, sowie ausführliche morphologische und oekologische Angaben über die in Grossbritannien und Irland beobachteten Arten, im ganzen 11, darunter 3 neue.

Die Corophien leben in seichtem Wasser und bilden alle, soweit bekannt, Röhren aus Schlick oder schlickigem Sand, entweder im Boden selbst oder auf Schwämmen, Ascidien, und ähnlichem Substrat. Manche sind besonders häufig in Flussmündungen und Häfen, wo ihnen viel Schlick zur Verfügung

steht, und ertragen dementsprechend geringe Schwankungen im Salzgehalt sehr gut. Andere gehören zur typischen (mesohalinen) Brackwasserfauna; einige leben schliesslich in süssen oder nahezu süssen (oligohalinen) Gewässern.

Die wichtigsten Merkmale zur Unterscheidung der *Corophium*-Arten liefern: das Urosom, das erste Glied der ersten Antenne und das 4. und 5. Glied der zweiten Antenne. Die Verschiedenheiten im Bau des ersteren haben Veranlassung gegeben, das Genus in drei Sektionen aufzuteilen: A. die Glieder des Urosoms sind nicht miteinander verschmolzen; B. die Glieder sind verschmolzen, die Uropoden I und II sind lateral angeheftet; C. die Glieder sind auch hier verschmolzen, Uropoden I und II sitzen jedoch ventral. Weitaus die Mehrzahl der beschriebenen Arten, 19, gehören zur ersten Sektion; in die zweite kommen 8, in die dritte 5 Arten.

Die britischen Vertreter dieser drei Sektionen sind: —

Sektion A: *C. volutator* Pallas, *C. arenarium* nov. spec., *C. curvispinum* G. O. Sars var. *devium* Wundsch, *C. affine* Bruzelius.

Sektion B: *C. crassicorne* Bruzelius, *C. bonelli* G. O. Sars, *C. insidiosum* nov. spec., *C. acherusicum* da Costa, *C. sextoni* nov. spec.

Sektion C: *C. acutum* Chevreux, *C. lacustre* Vanhöffen.

Von diesen sind *C. volutator, bonelli* und *lacustre* auch als Bewohner vieler Brackwassergebiete des europäischen Festlandes bekannt. *C. acherusicum* ist marin und wurde z.B. in der ehemaligen Zuidersee nur in der polyhalinen nördlichen Übergangszone gefunden. Auch *C. crassicorne* scheint eine polyhaline Art zu sein und nur stellenweise in grösseren Mengen vorzukommen. Ihre Verbreitung ist nicht genau bekannt, da sie wiederholt mit anderen Arten *(C. acherusicum, bonelli, lacustre)* verwechselt wurde. Eine Nachprüfung des *sub nom. C. crassicorne* eingesammelten und aufbewahrten Materials erscheint daher sehr erwünscht. *C. curvispinum* var. *devium* schliesslich ist eine richtige Süsswasserart, die von Osteuropa bis an die Elbe verbreitet ist, doch im Rhein—Maasgebiet bis jetzt noch nicht beobachtet wurde. Um so merkwürdiger erscheint daher ihr Vorkommen in England, in dem Avon bei Tewkesbury, wo sie vom Verfasser im Jahre 1935 entdeckt wurde.

Von den drei neuen Arten ist *C. arenarium* nahe verwandt mit *C. volutator;* sie unterscheidet sich von letzterer hauptsächlich durch ihre geringere Grösse. Vielleicht handelt es sich hier nur um eine Varietät. *C. insidiosum*, in der Literatur öfters mit *C. bonelli* verwechselt, ist charakterisiert durch die eigentümliche Anordnung der Stacheln auf den Antennen. *C. sextoni* scheint mit *C. acherusicum* verwandt zu sein. Sie war 1934—1935 die häufigste Art im seichten Wasser des Plymouth Sound und hat sich dort anscheinend erst nach dem Jahre 1911 angesiedelt. Woher sie kam, konnte bisher jedoch noch nicht festgestellt werden.

Die Arbeit enthält recht ausführliche Literaturangaben für die einzelnen Spezies, kurzgefasste, übersichtliche Notizen über deren Verbreitung und wichtige oekologische Bemerkungen über die Beschaffenheit der Fundstellen. Nur fehlen leider in den meisten Fällen Angaben über den Salz- resp. Cl-Gehalt der untersuchten Gewässer.

Die kritisch-systematischen Ausführungen des Verfassers, seine Angaben über den Bau der einheimischen Arten, sowie die Beschreibungen und Abbildungen der *novae species* werden den Forschern, die sich mit Untersuchungen über den Mageninhalt der Fische beschäftigen, besonders willkommen sein. Denn bekanntlich spielen die Corophien sowohl in den Aestuarien wie im stehenden Brackwasser eine bedeutende Rolle als Fischnahrung und zu ihrer richtigen Bestimmung kann Crawfords neueste Zusammenstellung ausgezeichnete Dienste leisten.

H. C. R.

G. I. Crawford. "Notes on the Distribution of Burrowing Isopoda and Amphipoda in Various Soils on the Sea Bottom near Plymouth." Journ. Mar. Biol. Assoc., N.S., Vol. XXI, No. 2, pp. 631—646, 1 Fig. Plymouth, 1937.

Der Verfasser berichtet in der vorliegenden Arbeit über die von ihm in den Jahren 1934 und 1935 in der Nähe von Plymouth gesammelten marinen Isopoden und Amphipoden im Zusammenhang mit der Beschaffenheit des Bodens an den Stellen, wo sie gefangen wurden. Anschliessend an Allens frühere Untersuchungen unterscheidet er acht Feinheitsstufen beim Bodenmaterial, von Steinen hinab bis zum Schlamm. Zu quantitativen Arbeiten reichte die zur Verfügung stehende Zeit nicht aus; auch fehlte ein geeigneter Bodengreifer. Immerhin lassen die mittels Dredgen verschiedener Konstruktion gewonnenen Ergebnisse einige Schlüsse zu über das Vorkommen einer grösseren Zahl von Arten auf den ihnen offenbar am meisten zusagenden Bodentypen. Näheres hierüber ist im Original nachzusehen.

H. C. R.

G. I. Crawford. "The Fauna of Certain Estuaries in West England and South Wales, with Special Reference to the *Tanaidacea, Isopoda,* and *Amphipoda.*" Journ. Mar. Biol. Assoc., N.S., Vol. XXI, No. 2, pp. 647—662, 2 Fig. Plymouth, 1937.

Diese Arbeit bildet gewissermassen eine Fortsetzung und Vervollständigung der im Jahre 1929 von E. Percival veröffentlichten Ergebnisse seiner Untersuchungen in den Aestuarien des Tamar und Lynher, über die Referent seinerzeit ausführlich berichtet hat*). Sie enthält ausserdem eine Reihe von neuen Beobachtungen aus dem Mündungsgebiet einiger kleinerer englischer Flüsse: Plym und Exe (S.Devon), Taw (N.Devon), Camel (N.Cornwall) und Towy (S.Wales). Da der Autor fast ausschliesslich im brackischen Bereich dieser Flussmündungen gesammelt und sich dabei speziell mit den dort lebenden Arthrostraken eingehend beschäftigt hat, bildet auch diese Arbeit einen wertvollen Beitrag zur Literatur über die westeuropäischen Brackwassergebiete.

Infolge seines eingehenden Studiums der betreffenden Tiergruppen sah der Verfasser sich veranlasst, zahlreiche unrichtige Bestimmungen von Isopoden und Amphipoden, die sich in der neueren Brackwasserliteratur vorfinden, zu berichtigen. Somit bildet der Abschnitt "Brackish-Water Crustacea in England" (in der zugehörigen Tabelle I sind allerdings nur die *Tanaidacea, Isopoda* und *Amphipoda* verzeichnet), meiner Ansicht nach den wertvollsten Teil der Arbeit. Indem ich für Einzelheiten in Bezug auf das Vorkommen und die Verbreitung der vom Verfasser beobachteten Arten auf das Original verweisen muss, möchte ich mit einigen Bemerkungen mehr allgemeiner Natur schliessen.

Zunächst ist es zu bedauern, dass auch hier genaue Angaben über den Salzgehalt der untersuchten Gewässer fehlen. Der Verfasser weist zwar für den Tamar und Lynher auf die seinerzeit von Percival veröffentlichten Daten hin, aber wie ich schon früher (*l.c.*, p. 246) betont habe, beziehen sich diese offenbar auf die Oberfläche und haben somit für die Oekologie der am Boden der Aestuarien lebenden Tiere nur geringen Wert. Über den Salzghalt der übrigen untersuchten Flussmündungen wurden keine Beobachtungen angestellt; der Autor ist daher gezwungen, sich zu beschränken auf allgemeine Ausdrucke wie "brackish water", "saltmarshes", "water of low

*) Journ. du Conseil, Vol. V, No. 2, 1930, pp. 245—247.

salinity" u. dgl. Nur von *Corophium insidiosum* erfahren wir (p. 659), dass es "among weeds in water of rather high salinity (ca. 20‰)" lebt.

Ich bin davon überzeugt, dass der Verfasser, falls er über genügend Beobachtungen über den aktuellen Salz- resp. Cl-Gehalt an seinen Stationen verfügt hätte, zu der Einsicht gelangt wäre, dass es tatsächlich möglich ist, "to define the term 'Brackish-Water Species' in terms of salinity" (p. 655), sogar in Aestuarien, obwohl die Schwankungen im Salzgehalt hier selbstverständlich bedeutender sind als im stehenden Brackwasser des Flachlandes. Immerhin ist es nach ihm möglich "in the fauna of an estuary to distinguish certain species which belong more properly to fresh water ...., or to the sea ...., than to brackish water" (p. 655). Lässt man diese aus den Fangverzeichnissen fort, dann bleiben 14 Brackwasserarten aus den genannten Gruppen übrig, die sämtlich (mit Ausnahme von *Corophium lacustre*) vom Verfasser in den südwestlichen englischen Flussmündungen nachgewiesen wurden. Diese 14 Brackwasser-Crustaceen sind nun aber in der Mehrzahl gerade diejenigen, die auch in den mesohalinen Brackwassergebieten des westeuropäischen Festlandes als autochthone Arten zu Hause sind. Das Vorkommen spezifischer Brackwassertiere ist somit nicht, wie der Autor vermutet, nur von lokaler Bedeutung, sondern eine allgemeine Naturerscheinung.

H. C. R.

R. Spärck. "The Benthonic Animal Communities of the Coastal Waters". Zoology of Iceland, Vol. I, Part 6, 45 pp., 5 Fig. Copenhagen and Reykjavik, 1937. (Kr. 4·50).

At the instigation of Dr. Spärck a committee was formed in 1931 to organize field studies in Iceland with the ultimate object of preparing a Fauna of that country. Publication has now been begun and five volumes will be issued. The first will deal with introductory matters and with general zoology; volumes two to four will treat of systematics, while the fifth volume will be made up of papers dealing with general zoogeography. The area covered extends to the edge of the continental shelf, and the publication is planned to include all that is at present known of the Icelandic fauna. The scope is wide and the completed series should prove of great interest and service to marine biologists.

Dr. Spärck gives an account of the animal communities of the coastal area. In his introduction he discusses the validity of the community method, and the sense in which he uses it. Six communities of "infauna" and two of "epifauna" are described. The "infauna" communities are named after the following species: — *Macoma calcaria, Pontoporeia femorata, Yoldia hyperborea, Spisula elliptica, Amphiura filiformis,* and *Maldane sarsii:* the "epifauna" from *Mytilus edulis* and *Modiola modiolus.* The distribution of these various communities is shown on a chart, and tables are given showing the composition of each.

The *Pontoporeia femorata* community occurs in brackish water and is the only one in which crustacea play an important part. In it productivity is fairly low. In the other communities the weight of animals is greatest in the shallow-water bays and fjords and compares well with that of other areas. The shallow-water communities, *Macoma calcaria* and *Spisula elliptica,* are dominated by lamellibranchs. In the *Yoldia hyperborea* community, lamellibranchs, echinoderms and polychaetes are of almost equal importance, while in the deep-water communities, *Amphiura filiformis* and *Maldane sarsii,* echinoderms and polychaetes are the dominant forms.

A. C. S.

E. Wesenberg-Lund. "Gephyrea." Zoology of Iceland, Vol. II, Part 23, pp. 1—16, 3 Fig. Copenhagen and Reykjavik, 1937. (Kr. 1·50).

Eleven species of Gephyrea are recorded from Iceland, but one — *Onchnesoma squamatum* — does not come strictly within the scope of the book since it was taken beyond the edge of the shelf. The remaining ten species are divided into three groups, the first containing six species, *Priapulus caudatus, Phascolosoma margaritaceum, Ph. minutum, Phascolion strombi, Echiurus echiurus* and *Hamingia arctica,* which are widely distributed in boreal and arctic waters. With the exception of the last-named species, all occur on both sides of the Atlantic. The second group contains three species, *Priapulus bicaudatus, Halicryptus spinulosus* and *Phascolosoma eremita,* species which are truly arctic. The remaining species, *Sipunculus norvegicus,* is the only southern element amongst the Icelandic Gephyrea.

A synopsis of each species is given. There are three charts showing where the various species have been taken.

Gephyrea occur all round Iceland but are noticeably scarce in the shallow water along the south coast. This may be due to lack of collecting, since most of this was done in the fjords.

A. C. S.

G. Otto. "Fauna der Enteromorphazone der Kieler Bucht." Kieler Meeresforsch., Bd. I, H. 1, S. 1—48. Kiel, 1936.

The microfauna of the sea, except so far as the plankton is concerned, has received all too little attention from ecologists. So far as the littoral zone is concerned, the biology of most of the microfauna, such as nematodes, rotifers etc., is almost completely unknown, although they probably play an important part in the economy of the shore. In this paper Otto gives a very detailed account of the fauna of the *Enteromorpha* zone in Kiel harbour and the neighbourhood. The *Entermorpha* forms a band, 20—30cm. wide, above mid-tide level, and practically the whole of its fauna consists of micro-organisms. Ninety-six species of these are listed, of which two are new species. Nearly half the species found are nematodes, and the rest include Rhizopoda, Ciliates, Rotifers, Turbellaria, Tardigrades, Copepods, Ostracods, Acarina, etc. A number of these are figured, and after an account of the general chemical and physical conditions in the *Enteromorpha* zone, the range of conditions tolerated by each species is described. Finally the origin of the different constituents of the fauna, and their adaptation to the very extreme conditions existing in this zone, are discussed.

H. B. M.

S. Lund. "On the Production of Matter and the Growth in some Benthic Plants." Rep. Danish Biol. Stat. XLI, 1936, pp. 37—52, Fig. 8. Copenhagen, 1937.

The investigation of the growth-rate of marine plants is fraught with so many difficulties that, up to the present, it appears to have been impossible to obtain a clear idea of the productivity of even the commonest algae. Such observations as have been made are widely scattered, and the growth-rates indicated are extremely variable. So far as *Zostera marina* is concerned, various estimates of both the momentary stock and the yearly production

have been made, and these agree, at any rate in order of magnitude. For algae there are various estimates of the standing weight per unit area at different places, but most of the data on growth-rates are for short periods only and are of little use in attempting to calculate yearly production.

In the first part of this paper L u n d reviews some of the existing data, and in the second part he describes both the total algal growth found by him on concrete blocks, and the growth of individual *Fucus* plants of known age examined one and two years after the commencement of the experiments. In both parts of these experiments the observed growth varied greatly from place to place, and in the case of individual plants, from one plant to another. In view of this fact it would be well if more precise data could be given on two important factors — light intensity and degree of crowding. The general low level of growth obtained suggests that this was not an ideal locality for such experiments, but the results are nevertheless to be welcomed as an addition to our very inadequate knowledge of algal growth-rates.

H. B. M.

K. Larsen. "The Distribution of the Invertebrates in the Dybsø Fjord, Their Biology and Their Importance as Fish Food." Rep. Danish Biol. Stat. XLI, 1936, pp. 3—35, Fig. 9. Copenhagen, 1937.

The object of this investigation was the comparison of the food available on a given ground with the food taken by the fish feeding there. For this purpose Dybsø Fjord is very suitable as it is comparatively homogeneous in character, with a sandy and muddy bottom and harbouring a single type of community only, and is well isolated from the fjord outside, so that fish taken inside may well be taken to have fed exclusively within its limits. The fjord is about nineteen square kilometres in area, and one to two metres in depth. The dominant species is *Macoma baltica* (47% by weight), followed by *Cardium edule* (21%), *Mytilus edulis* (5%), *Littorina rudis* (4%), and *Nereis diversicolor* (3%). *Leander* and *Crangon* are also abundant. The first part of the paper deals with the distribution of these species, both in this and other Fjords, and the second part with the proportions in which they are found in the stomachs of various fish. Finally, in the last section, an attempt is made to assess the proportions in which the various food is utilized. This is done by taking the percentage of each food species as it occurs on the bottom and dividing this by the percentage in which it occurs in the fish stomachs. Thus a value approaching zero indicates a high degree of utilization. Some of the more important figures so obtained are shown below.

	Eel	Flounder	Cod	Sea-scorpion
Cardium exiguum	35·50	0·11	∞	3·18
C. edule	∞	1·03	∞	∞
Macoma baltica	∞	7·56	∞	∞
Rissoa spp.	∞	8·67	21·67	65·00
Idothea viridis	0·06	0·03	0·15	0·38
Leander adspersus	0·04	1·28	0·05	0·02
Corophium volutator ...	∞	18·00	∞	∞

It is unfortunate that the figures for such important species as *Leander*, *Mya*, and *Arenicola* are rendered of little value by the impossibility of sampling them adequately, but despite this, the interesting fact does emerge that the crustacea, excepting *Corophium*, are being utilized to a very high

degree while the molluscs, and especially the gastropods are hardly being utilized at all. Further, it is found that the young *Cardium*, living at the surface, are utilized far more than the deeper living *Macoma*.

Such a piece of work is admittedly incomplete, especially in the inadequacy of the number of fish stomachs examined, but it is of real value in attempting to give a quantitative figure to the relative value of the different available food sources as utilized by the fish.

H. B. M.

S. G. Segerstråle. "Studien über die Bodentierwelt in südfinnländischen Küstengewässern. III. Zur Morphologie und Biologie des Amphipoden *Pontoporeia affinis*, nebst einer Revision der *Pontoporeia*-Systematik." Soc. Sci. Fennica, Comment. Biolog. VII, I. S. 183, Abb. 9, Taf. XIX. Helsingfors, 1937.

Continuant ses recherches sur la faune benthique des eaux côtières du sud de la Finlande, M. Sven G. Segerstråle nous donne une intéressante monographie d'un Amphipode particulièrement abondant dans cette région, le *Pontoporeia affinis*. Comme il convient, l'auteur commence par l'étude systématique du genre et montre que, des nombreuses espèces proposées, deux seulement sont à retenir: *Pontoporeia affinis* Lindstroem et *P. femorata* Kröyer. Les *P. filicornis, Kendali, Weltneri* se rattachent au *P. affinis* et le *P. sinuata* au *P. femorata* dont ils ne sont que des individus ♂ hautement différenciés. Il en est autrement d'une forme à antennes courtes des eaux douces de l'Amérique du N. *(P. brevicornis)* qui est le ♂ d'une forme spéciale de *P. affinis*, dont la différenciation remonte sans doute au moment ou les lacs ont été isolés de la mer.

Quant au *P. affinis*, il est l'objet d'une étude détaillée dont nous retiendrons seulement les points les plus caractéristiques. Cette espèce présente un dimorphisme sexuel trés net déjà connu dans son ensemble; mais l'auteur insiste avec raison sur une particularité des ♀ qui n'avait pas encore été signalée, le développement remarquable de leurs branchies, et sur la variabilité des ♂ adultes suivant la profondeur ou la localité d'où ils proviennent.

En réalité c'est en étudiant la biologie du *P. affinis* que M. Segerstråle a trouvé le plus de nouveautés. Les premières femelles ovigères font leur apparition vers le milieu de novembre et la ponte est achevée à la fin de décembre. L'accouplement qui se fait la nuit dans le plancton ne semble précédé d'aucun préliminaire analogue notamment au chevauchement si fréquent chez les Gammariens; il fait rapidement suite (2 jours environ) à la dernière mue de la femelle. Celle-ci pond en moyenne 30 à 40 oeufs; ce nombre est souvent beaucoup plus élevé: l'auteur en a trouvé jusqu'à 74 mais tous alors ne semblent pas arriver à complet développement et certains sont éliminés. Le développement s'effectue ainsi durant la saison froide, à une température à peine supérieure à 0°; il est en conséquence fort long puisque c'est seulement en mars-avril, c'est-à-dire au bout de 4 à 5 mois, que se produit l'éclosion. Les mâles ayant atteint leur maturité ne semblent pas prendre de nourriture et ont une existence très brève, d'une semaine à peine; déjà rares au début de décembre, ils ont complètement disparu au milieu de janvier. Les femelles ne survivent pas à l'éclosion; elles ne produisent donc chacune qu'une génération et ont presque toutes disparu en mai. Nous sommes donc en présence d'une espèce chez laquelle les adultes ne vivent exactement que le temps nécessaire à assurer la reproduction. Ce fait est

certainement à l'origine en relation avec le climat particulièrement froid et l'été bref des régions septentrionales mais il semble en être de même à la limite sud de sa répartition actuelle. Il est vrai que là le *P. affinis* est considéré comme un relicte glaciaire.

En tous cas, il est extrèmement remarquable que la ponte, qui pour les femelles marque l'achèvement du cycle vital, peut se produire tantôt à 1 an, tantôt à 2 ans, tantôt à 3 ans, suivant les individus et suivant la profondeur à laquelle ils vivent. Ainsi, dans le Tvärminne, sous une épaisseur d'eau de 1·5m., les femelles meurent au bout de 1 an, à une profondeur de 19—20m. au bout de 2 ans, et au-dessous (36—44m.) au bout de 3 ans. A 30m. en effet, la température moyenne est d'environ 3·5°C. tandisqu'elle est voisine de 7°C. en surface. Le développement se fait donc plus rapidement dans les couches supérieures, la maturité y est atteinte plus tôt et la vie y est plus brève.

L'auteur a étudié également les migrations verticales et horizontales des individus. Aux premières qui s'effectuent de nuit prennent part, contrairement à ce qui a été observé pour d'autres *Haustoriidae*, les individus de tout âge et de tout sexe; les ♂ toutefois demeurent en surface beaucoup plus longtemps. Quant aux migrations horizontales, elles sont relativement peu importantes et sous l'entière dépendance des courants.

Enfin une partie du travail de l'auteur, et qui n'est pas la moins originale, traite des fluctuations annuelles de l'espèce dans cette région de Tvärminne qui est à l'entrée du Golfe de Finlande. En ce point, régulièrement étudié depuis 1928, on a constaté une raréfaction graduelle du nombre des individus qui est tombé en 1933 à 1% de ce qu'il était cinq ans auparavant. Ce pourcentage s'est relevé depuis; mais en 1935 il n'était encore que de 5·7%. La cause de ces fluctuations n'apparaît pas clairement; mais celles-ci ne sont pas indifférentes puisque *Pontoporeia* affinis joue un rôle important dans l'alimentation de toute une série de poissons comestibles tels que l'Eperlan, les Gades, les Pleuronectes, les Corégones et aussi du gros Isopode *Mesidotea entomon* que recherchent également avec avidité les mêmes poissons.

L. F.

O. Nybelin. "Untersuchungen über die Ursache der in Schweden gegenwärtig vorkommenden Krebspest." Medd. fr. Statens Undersökn. Försöksanst. f. Sötvattensfisket. Nr. 9. Stockholm, 1936.

E. Rennerfelt. "Untersuchungen über die Entwicklung und Biologie des Krebspestpilzes *Aphanomyces astaci*, Schikora." Ibid., Nr. 10. Stockholm, 1936.

It is well known that both European species of crayfish, *Astacus fluviatilis* and *A. pallipes*, are very subject to epidemic disease. So severe are these epidemics that the animals become almost extinct in rivers where a year or two earlier they were present in abundance. It is natural that on the continent, where the larger species *A. fluviatilis* is important commercially as an article of food, this subject should attract a good deal of attention and several diseases affecting crayfish have been described. It has for long been thought that one of the main agents causing these epidemics was a bacillus discovered by Hofer and called by him *B. pestis astaci* (*Allgemeine Fischerei Zeitung* 1898) though in 1903 Schikora described a fungus *Aphanomyces astaci* which was found on diseased crayfish and claimed that this was the cause of the disease (*Fischerei Zeitung* 1906).

In the first of these papers Dr. Nybelin gives a very interesting description of his investigations into these conflicting claims. From diseased crayfish from Swedish lakes he was able to isolate a bacterium apparently exactly similar to *B. pestis astaci* as described by Hofer but he was unable to satisfy himself of its pathogenicity and showed by agglutination tests that it was identical with some strains of the very variable *B. proteus.* As he quite rightly remarks, he has not proved that Hofer's *B. pestis astaci* is a strain of *B. proteus* for Hofer's cultures no longer exist and the agglutination test, the final proof, cannot now be applied, but he has certainly established a strong *prima facie* case for this view. He then examined the fungus *Aphanomyces astaci* which was present on the diseased crayfish and showed that it is a parasite of the skin and central nervous system only. After overcoming the difficulties of contamination with bacteria, a very regular accompaniment to research on the water fungi, he was able to show that this fungus can by itself produce the disease in its typical form, and he concludes therefore that Schikora was right and that the fungus is the real cause of the disease and the various bacteria which have been described are secondary infections.

He does not claim that *Aphanomyces astaci* is the only organism responsible for epidemics among crayfish, and indeed both a microsporidian *Thelohania contejeani* and an oligochaete *Branchiobdella parasitica* have been found to cause a considerable mortality, and there are probably others, but his evidence for the major importance of the fungus is based on sound and reliable observations.

In the second paper Dr. Rennerfelt gives a clear account of the structure, life history, and reproduction of the species. From his observations he concludes that the organism is probably an obligate parasite. He also gives an account of the effect of various fungicides on its growth, experiments undertaken with a view to methods of control being elaborated, but they have not yet gone far enough to have an immediate practical application.

F. T. K. Pentelow.

Current Bibliography.

Prepared by the Editor with the assistance of Miss Thursby-Pelham.

NOTE. The scope of the Bibliography is limited in the main to the area covered by the Council's activities, but there are included papers of general interest relating to other areas in North Temperate and Arctic regions and exceptionally elsewhere. Limnological references are not as a rule given, but papers relating to brackish waters and to salmon and freshwater fish studied by the Council are included.

The classification of entries follows in a general way that adopted in Dr. Allen's Selected Bibliography published in Vol. I, Nos. 1 and 2 of the Journal, and since reprinted.

Subscribers and those on the distribution list will receive regularly upon application to the Administrative Secretary copies of the Bibliography printed on one side of the page only, for use in making up card indices.

The Editor will be glad to be advised of emendations and additions to the Bibliography.

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